REFINER
AND NATURAL GASOLINE MANUFACTURER
A Gulf Publishing Company Publication

VOLUME 11, No. 10 OCTOBER, 1932

Let Capital Visit a Clinic

CAPITAL should submit itself to more critical examination. Its paramount purpose should be determined. The theory has been that the primary object of capital is to make a profit. If that is correct, business of all sorts should continue to drive ahead for profit.

But this theory becomes questionable when periods of profit are followed by periods of want. Either it is improper to devote the full force of capital to the making of profit, or those responsible for business have not learned how to make profit and how to distribute the winnings of endeavor.

When we have a surplus of food and hungry humanity, is it not in order to seek the reasons? Too much cotton and wool and too many children improperly clad are not an attractive answer for any system. There is too much gasoline and too many people chained to the confines of their strength to walk.

Lincoln Steffen, who was once and perhaps still is a socialist, tells the world that the surplus goods of the world should be known as plenty. He would have the black spot of unemployment transformed into leisure. Unfortunately he gives no methods.

Can capital find a method? That might be a sound basis on which to examine capital. Instead of a profit as its primary consideration, why should capital not make its first consideration the welfare of humanity? That accomplished, perhaps profit would take care of itself.

The five-day week, adopted as permanent policy, is a step toward the welfare of humanity. If capital and labor with the aid of the machine can supply the essentials and luxuries of life by keeping men at their tasks but five days out of seven, it becomes the duty of capital to provide the solution. Then men will indeed have the benefits of the science and invention.

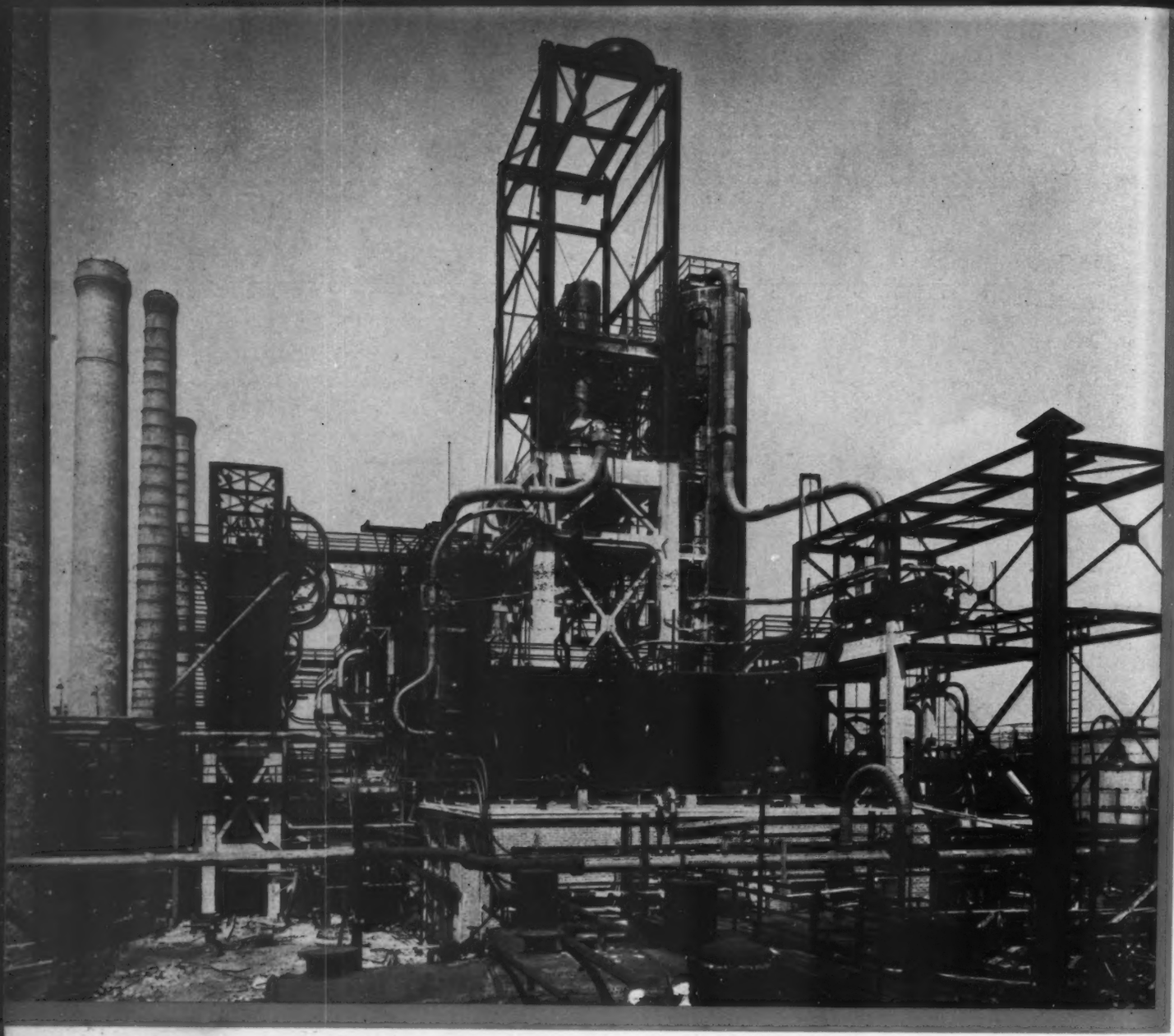
So far there has been but trivial adoption of insurance against unemployment and retirement. These offer rewards well worth the study necessary to determine their soundness. Insurance experts have determined the life span with such exactness that rates can be fixed to assure payment in funds equal to the policy written. Perhaps these men can determine the span of employment with equal exactness and thus determine what part of wage and earnings should be set aside to take care of the day of no job.

Both worker and capital could contribute to this form of insurance at ratios properly determined. If the employer as well as the worker were compelled to divert small parts of wage and earnings to this cause, there would be less of profit for expansion, which is not always wise. Thus insurance could have a double throttle on the conduct of business. It would retard expansion on the part of capital and at the same time require the wage earner to accumulate a reserve, which ordinarily goes into the purchase of commodities that run far afield of essentials.

There are scores of possibilities, as yet not even attempted by individual concerns. This should be but one phase of the inquiry to which capital should subject itself to determine what should be its ultimate aim.

Such an inquiry should be undertaken by capital. The enemies of capital are already convinced that it serves no good purpose. But no man familiar with history can in honesty hold that conviction. There is great accomplishment to the credit of capital. It has reached many of its goals. Now the question arises—should it attempt to reach other goals? Should some goals formerly held dear be pushed into the background?

Neither should capital fear such an examination. Unless it can serve better than any other combination of labor and distribution, it should give way to a still better plan. Only the rash are convinced that capital can not reach this position. That it has deficiencies is evident; that it has the power to overcome these deficiencies is also evident.



Modern Design *in* Tide Water Cracking Facilities

JOHN J. MACK
Design Superintendent, Engineering Department, Tide Water Oil Company

(Photos Courtesy The Lummus Company)

TIDE Water Oil Company, as a further step in its program of modernization of its Bayonne refinery and to supplement its present cracking facilities, has recently constructed and placed into operation a new cracking coil of the "Tube and Tank" type. The basic design for this unit was worked up by the personnel of Tide Water Oil Company, who have had extensive experience in the operation of similar units. The detailed design and construction were done by The Lummus Company.

The plant is a double unit, consisting of duplicate furnaces and high pressure system connected to a common secondary or fractionating system. This arrangement proved to be very effective in the reduction of capital investment required for the unit. On cracking coils of this type, the fractionating and condensing

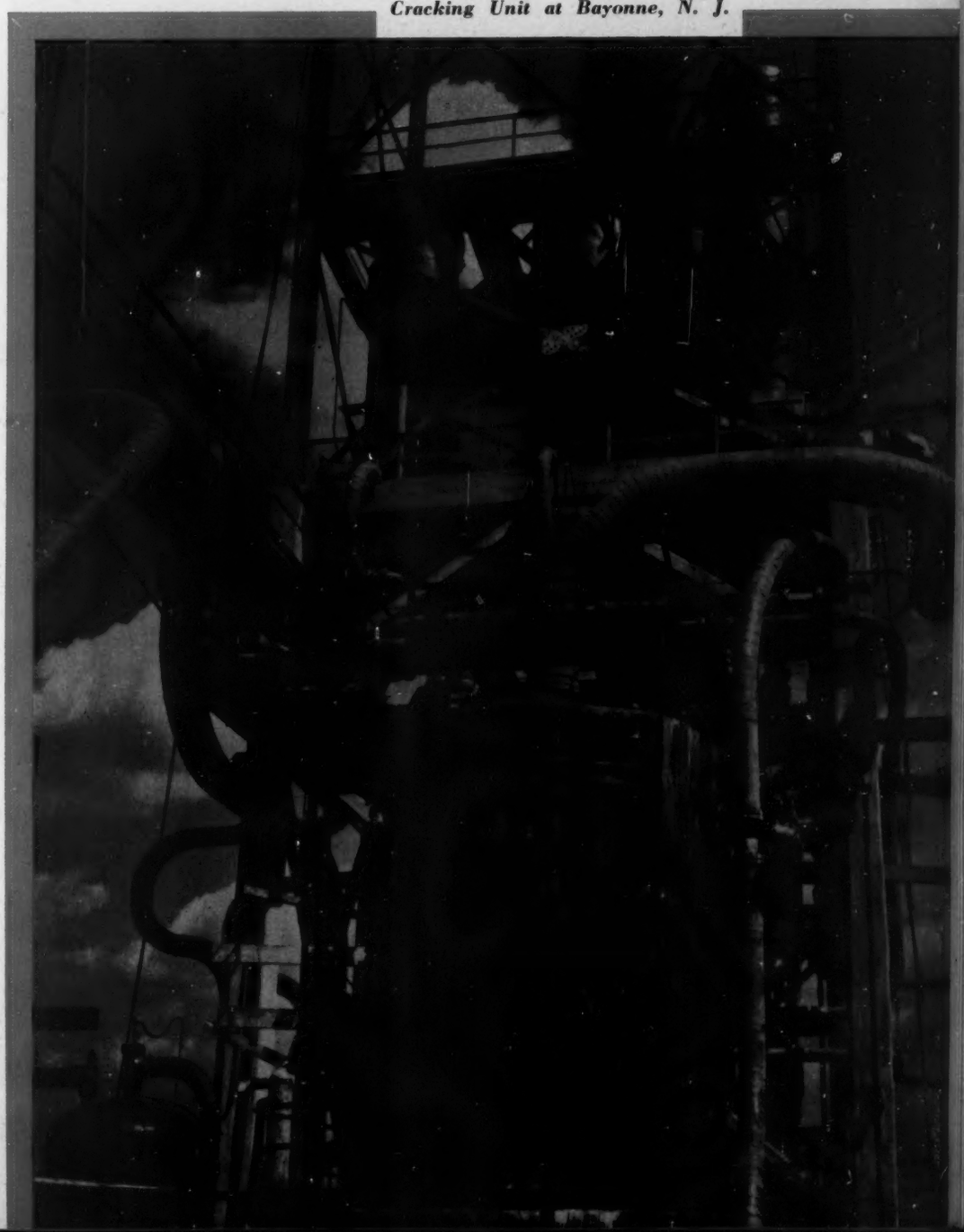
THE trend in cracking unit design is not only toward larger capacities, but includes the use of multiple furnaces, wherein two cracking coils, discharging into a common secondary system lend much to flexibility of the installation. In this article, John J. Mack, Design Superintendent for Tide Water Oil Company, interestingly describes the design and operating features of this very modern plant.

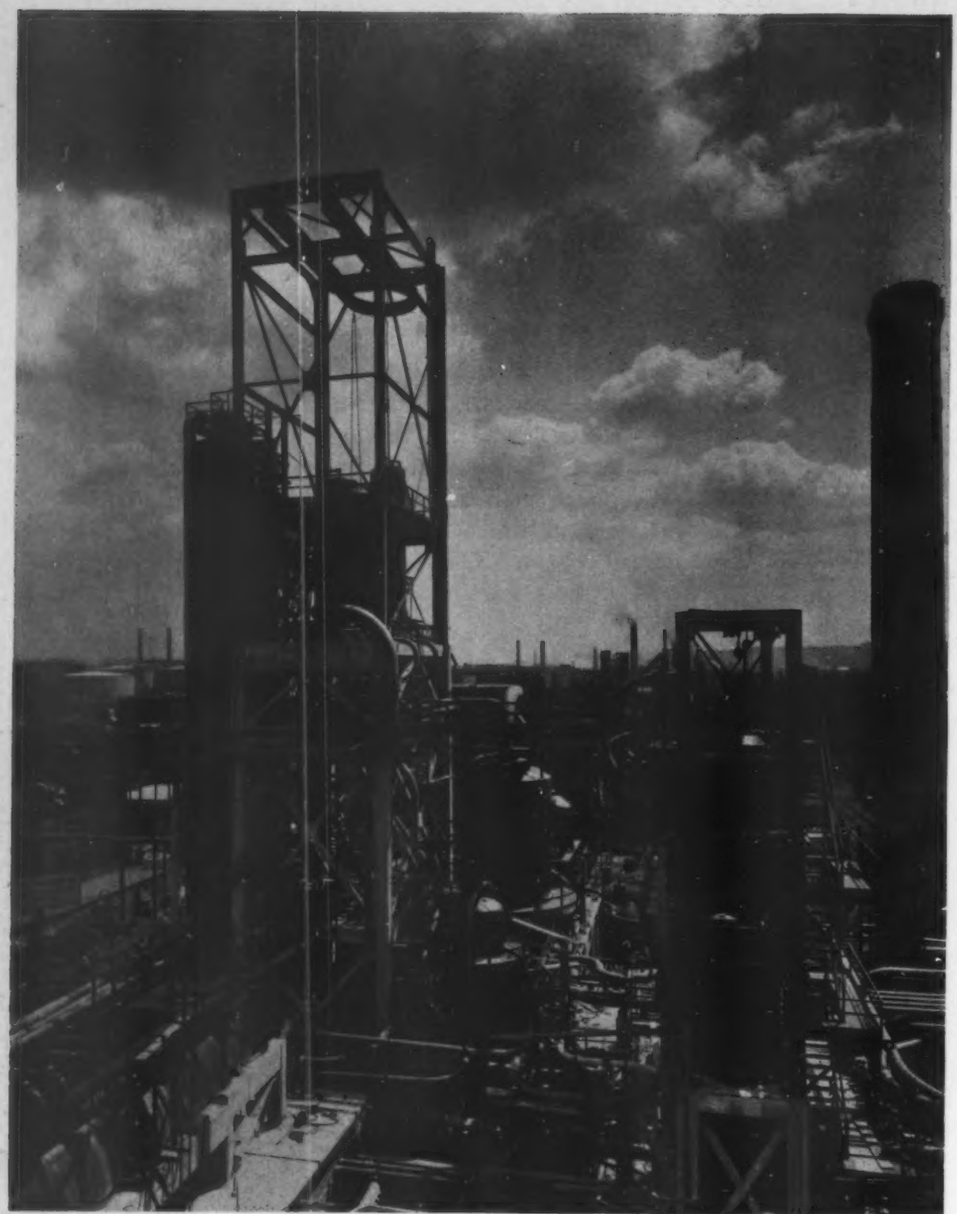
system is so reliable that it almost never causes trouble or occasions shut-downs. Because of this, it is feasible to eliminate individual fractionating systems and to operate two heaters on a common secondary system, thereby saving the cost of the additional towers, condensers and lines. In operation, this system has worked very satisfactorily. Each heater can be shut down individually for cleaning without disturbing the continuity of operation of the fractionating system.

Briefly, the flow is outlined as follows:

The cold, fresh feed charging stock is pumped from storage through two low pressure vapor heat exchangers in which it picks up preheat from the vapors from the fractionating tower. From the exchangers, the charging stock passes to the hot oil accumulators, of which there is one for each heater. In the accumulator the charging stock is mixed with the recycle stock. The accumulators and exchangers are so connected that it is possible to process two separate charging stocks simultaneously. In normal operation, one coil is operated on gas oil, the cycle stock for which is collected in the base of the fractionating tower, while the other coil is operated on a light gas-oil cut, the cycle stock for which is withdrawn as a side stream from the fractionating tower. The hot charging pumps pump the cycle stock from the accumulators through a battery of high pressure heat exchangers. In this case, the heating medium consists of hot cracked vapors from the separator passing on to the fractionating tower. These vapors contain heat greatly in excess of the requirements of the fractionating tower, which, if not removed at this point would require greatly increased quantities of reflux over the tower which in turn would require additional condensing equipment as well as placing a more severe load on the tower. The absorption of this excess heat by the cycle stock in the high pressure heat exchangers raises the temperature of the cycle stock entering the heaters, resulting in a very material reduction in furnace load and a definite saving in the fuel required. The value of the high pressure exchangers increases

Heat Exchangers in Tide Water Oil Company's New Tube and Tank Cracking Unit at Bayonne, N. J.





Fractionating equipment, soaking drums, exchangers, piping and details of construction are shown in this striking illustration.

very rapidly with the rise in gravity of the charging stock since, with light stocks it is necessary to maintain low accumulator temperatures to prevent boiling.

The preheated cycle stock enters the heater where it is raised to the proper temperature. From the heater it passes to the soaking drums in which it is held for a sufficient time to complete the cracking reaction. The oil flows through a manually operated pressure release valve from the soaker into the separator. The streams from both heaters are united at this point. Tar is removed continuously from the bottom of the separator, which is of the vertical type. The overhead products from the separator pass through the high pressure heat exchangers as mentioned above, to the fractionating tower. In the tower, the vapors are condensed and fractionated into the separate recycle stocks and the overhead products which are end-point gasoline and gas. The condensing equipment consists of a combination of a submerged box type condenser coil with shell and tube final coolers. Cold reflux is pumped back over the tower. The finished product flows from the unit to the surge drums of a stabilizer plant under its own pressure. Provision is also made for the withdrawal of a side stream from the fractionating column.

The cracking coils were designed to process 8000 (42-gallon) barrels per day of fresh feed charging stock. The combined feed to the heaters, consisting of recycle stock and fresh feed, was to be 12,000 barrels per day per heater.

The high pressure system was designed to withstand a soaking drum pressure of 1000 pounds per square inch. The secondary system was designed for a maximum pressure of 150 pounds per square inch.

In subsequent operation of the coils, it was found that the estimated throughputs could be exceeded by a very comfortable margin and that improved yields of gasoline were easily possible.

A brief description of the main pieces of equipment involved in the operation follows:

The furnace is designed for the absorption of the major portion of the heat in the radiant section. As mentioned above, the circulation rate is 12,000 barrels per day of hot oil. The heat absorbed by the oil in passing through the heater is 40,000,000 B.t.u. per hour. The radiant section of the furnace resembles a large box. It is approximately 33 feet long by 28 feet wide by 22 feet high. The total volume of this section is 20,000 cubic feet, resulting in a heat liberation of only 3000 B.t.u. per cubic foot.

The comparatively large volume of the radiant section permits placing the tubes well out of the path of the products of combustion so that there is no flame or gas impingement. Heat absorbed is by radiation only. It has been found that when firing the furnace at its rated capacity, the furnace condition is so mild that there is

scarcely enough brilliance in the combustion chamber to view the tubes. The gases from the radiant section pass under an air-cooled suspended bridge wall into the convection section and thence to the stack. All walls, including the bridge wall, are of the suspended refractory type, air-cooled by natural draft. The floors of the furnace are air-cooled. The roof is the conventional flat arch type.

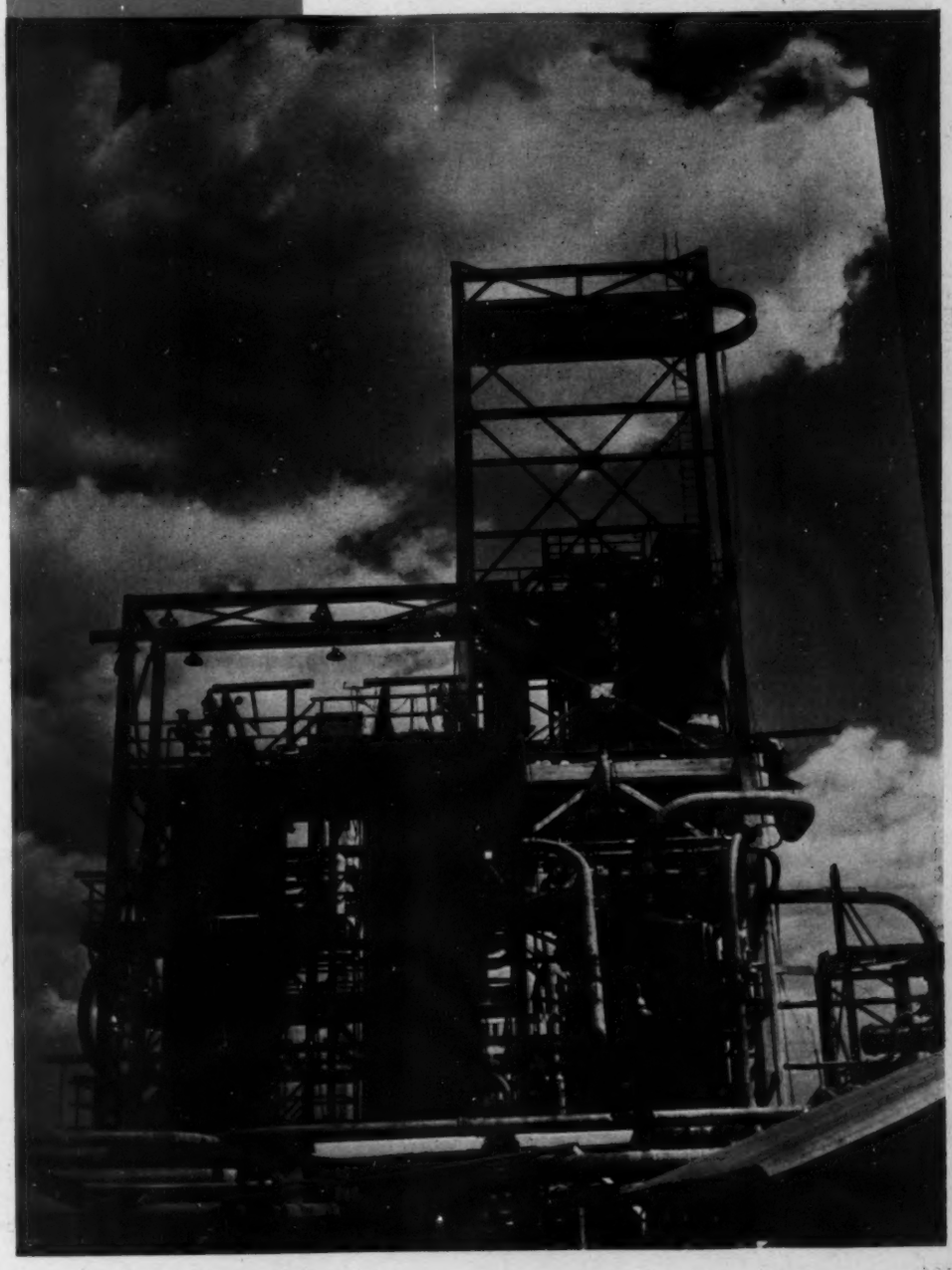
The tubes in the radiant section are arranged in a single row, across the roof and along the four walls. The oil flows in two parallel paths through the convection section and the wall tubes and in single path through the roof tubes. The symmetrical tube arrangement will permit a variety of flows through the heater if it is found desirable to change the present arrangement. All tubes in the radiant section, with the exception of the side wall tubes, are Nirosta KA_2S, 30 feet long, 4-inch outside diameter, by 0.4-inch wall thickness. The side wall tubes and the convection section tubes are made of low carbon steel and are also 4-inch outside diameter by 30 feet long. The total heating surface supplied is approximately 5000 square feet. The heat absorption rate at no point in the furnace exceeds 10,000 B.t.u. per square foot per hour.

The furnaces are fired from the sides by combination oil and gas burners of the inspirating type. The fuel normally used is gas produced by the unit.

The two soaking drums are each 70 inches inside diameter by 40 feet high with an average wall thickness of seven inches. The drums were hot forged and pierced from a single billet of steel and are without any seams or joints. The drums are designed for a working pressure of 1000 pounds at 900° F. and were subjected to a hydrostatic test of 3000 pounds per square inch. Back pressure on the drums is maintained in the control house by a valve manually operated through an extended shaft and gearing.

The separator is of the vertical type, 11 feet in diameter by 45 feet high with a wall thickness of 1⅜-inch, designed for a working pressure of 150 pounds. This vessel, as well as the other equipment in the low pressure system, has fusion welded joints, completely stress relieved and built in accordance with the A.S.M.E. Code for Unfired Pressure Vessels—Class One fusion welding. The separator is equipped with several baffles to knock back entrained tar and near the top has two bubble plates. Either fresh gas oil or condensate from the high pressure exchangers is refluxed over these plates. This washes the vapors free of entrained tar or coke and lowers the temperature entering the high pressure heat exchangers. The result is very little trouble with coke in the exchangers and a good color recycle stock withdrawn from the base of the bubble tower.

The fractionating tower is a combination bubble



View of the reaction chambers, or soaking drums, at the Tide Water cracking Plant.

Gas Engine Driven Hot Oil Charging Pumps, charging Gas Oil.

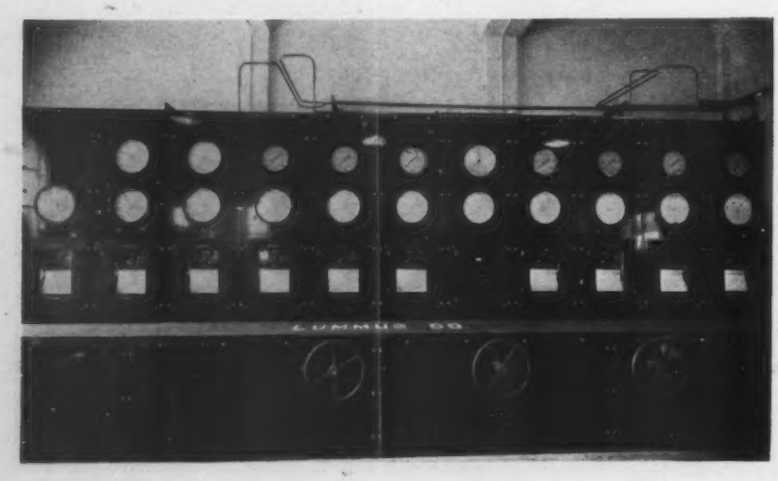
tower and hot oil accumulator. It is 12 feet in diameter by 90 feet high with a wall thickness of 1 7/32 inches. The weight of the tower is 325,000 pounds. This tower was completely built in the shops of the contractor, shipped and erected in one piece. It is believed to be the largest piece of refinery equipment ever so handled. The tower has 25 bubble plates with provisions for the withdrawal of a side stream from various points in the tower.

The hot oil charging pumps are of the crank and flywheel duplex type with outside packed plunger. Each pump has a 5½-inch bore by 24-inch stroke, with a piston displacement of 26,100 gallons per hour at 46 r.p.m.

Each pump is connected through a reducing gear to a simplex, double-acting, tandem gas engine, 20-inch bore by 30-inch stroke. The speed of these engines may be varied between 70 and 140 r.p.m. and is controlled by a throttling governor which regulates the quantity of air and gas fed to the cylinder, automatically maintaining the correct air-gas ratio.

The engines use as a fuel, gas made at the cracking plant. This gas normally contains 300 mg. of H_2S per 100 cubic feet, and if used untreated, would be very corrosive. The gas is allowed to bubble through a 10° Be. caustic solution in a coke-packed drum equipped with a mist extractor. This very effectively removes all hydrogen sulphide.

The gas pressure to the engines is controlled by two reducing valves working in series. The first reduces the gas pressure to two pounds and the second from two pounds to about one-

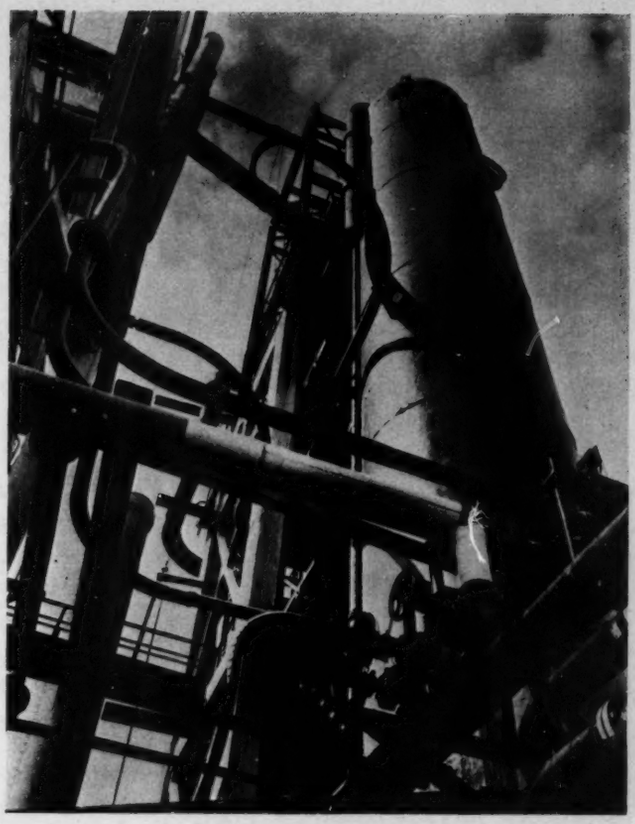


Control Board in the operating room at Tide Water Oil Company's new cracking plant.

half-inch water pressure. A small drum placed between the valves eliminates any tendency to hunt.

Pending completion of the main gas absorption towers, it has been necessary to erect a small coke packed absorber to insure a gas of constant heat value to the engines. This tower was made from a second-hand drum, 30 inches in diameter by 30 feet high, packed with 16 feet of coke with a mist extraction section. Charging stock is used as the absorption oil. While not very effective from the point of view of absorption efficiency, the tower does remove most of the heavier constituents and irons out the gas to a constant heat value. It has been found that a gas with very minor variations in heat content is essential to the smooth operation of the engines.

The unit is completely equipped with temperature and pressure recording and control instruments and liquid level indicators. With these instruments, a complete knowledge of conditions in all parts of the equipment is instantly available to the operators who can thus anticipate and eliminate any troublesome conditions. Results of operations to date indicate that the unit will be very satisfactory in every respect.



The fractionating column and necessary piping.

Below: Gas Engines Operating Charging Pumps at the Tide Water plant.

A MARKET EXISTS *for*

High Grade Fuel Oils

Made from Cracked Residua

DR. R. T. GOODWIN

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THE author stresses the increasing importance to the refiner of fuel oil as a co-product of intrinsic value, rather than as a by-product of gasoline production. In support of this contention, he points out that the demand for Diesel fuels for domestic heating is rapidly increasing, and that in order to supply this demand, refiners should utilize cracked residua as a source of industrial and Diesel fuel, road oil and lower viscosity bunker fuels.

There are several difficulties attending the use of residuals, chief among these being the deposition of solid hydrocarbons, during storage and handling. The tendency of consumers to insist upon low viscosities and freedom from b.s. and sediment has led refiners to the uneconomical practice of blending residuals with higher market value distillates to meet specifications. These conditions lead the author to the conclusion that the refiner should condition these residual products so that they may meet the needs of industrial, bunker and Diesel fuels, road oil and etc., which in his opinion, means stabilization by chemical and mechanical process which he describes. Such a stabilized pressure residuum, on account of its low viscosity, low pour and low b.s. and sediment content, can supply the needs of many attractive fields which to date have used distillates or blended fuels.

FUEL oil is an important product for the petroleum refiner both in terms of volume and dollars involved. The world's consumption of petroleum and its products in 1931 is estimated at 1,373,000,000 barrels. Of this total, 40 per cent was gasoline, 9 per cent kerosene, 43 per cent gas and fuel oils, 3 per cent lubricating oils and about 5 per cent miscellaneous products. Based on this division of products the United States consumed about 378,000,000 barrels of fuel oil in 1931, or a per capita consumption of gas and fuel oil of 129 gallons.

Consumption of gasoline is approximately equal in volume to that of gas and fuel oils, but due to the fact that the price of gasoline is about four times that of the other products, the refineries are operated primarily in terms of gasoline. The refiner is forced to produce the gas and fuel oils along with the gasoline, so should endeavor to market these products to advantage. In the past, fuel oils have been considered too much as "waste" or by-products to be disposed of, if necessary, at less than cost, and too little as potentially valuable co-products that will "pay their own way" if given some thought. This attitude regarding fuel oils is rapidly changing, however, and the refiner and marketer are realizing more that these products can be produced and marketed at a profit. In order to realize their full value, a definite plan must be formulated to produce the proper specification products for domestic, industrial, Diesel and bunker fuels.

For producing distillate fuels to special specification the modern fractionating equipment is indispensable. The demand for distillate fuels for domestic burners and high-speed Diesel engines is increasing rapidly and new methods must be utilized for producing industrial and heavy fuels from residual stocks.

The necessity for the refiners changing methods for producing the various grades of fuel oils, and more especially, industrial fuels, is demonstrated by the following figures: The A. P. I. petroleum stock report for September 10, 1932, shows gasoline stock as 35,189,000 barrels with gas and fuel oil stock 135,707,000 barrels. During this same week the gasoline stock was cut 634,000 barrels while the gas and fuel oil had a gain of 760,000 barrels. The gas and fuel oil would be divided about 10 per cent gas oil and distillate fuel or 13,570,700 barrels and residual fuel oils 90 per cent or 122,136,300 barrels. The A. P. I. Statistical Survey and Economic Forecast for the last nine months of 1932 show the total demand for

gas and fuel oil as 247,900,000 barrels and that December 31 would show 125,351,000 barrels in storage.

INDUSTRIAL FUEL

The largest growth in future demand for fuel oils will be for industrial fuels for heating of big buildings, hotels, etc. The Bureau of Mines report showing gas oil and fuel oil deliveries by uses, 1926-1930 shows the only consumption to increase materially in 1930 was fuel for heating of buildings, which increase was about 14 per cent.

Much of the fuel furnished for the heating of such buildings is a distillate product. A residual fuel could be used for apartment house, office building and factory heating where the burner is in operation most of the time and where a considerable volume is consumed. For this type of service a "stabilized" cracked residuum should be used, thereby releasing distillate fuels for other preferred services.

DOMESTIC FUEL

The very rapid expansion of oil burners for domestic heating in the next few years will cause a demand for distillate fuels which may be difficult for the refiner to supply. Since there are some types of domestic burners which will not operate successfully on a cycle stock or on pressure distillate bottoms, the refiner is forced to furnish a virgin gas oil, thereby placing the domestic fuel demand in competition with charge stock to cracking operations.

The past two years saw the entrance into the burner industry of some of the country's largest industrial groups, i. e., General Motors, through Delco Appliance; Westinghouse Electric with the Marr burner; Standard Oil Company through Gilbert & Barker; Kelvinator, through Maise Corporation (Rightway), and General Electric Company. With these well organized companies in the field, the domestic burner business should increase at a rapid rate. It is estimated that by the end of 1935 there will be installed 1,400,000 burners consuming an average of 50 barrels of fuel per year or a total of 70,000,000 barrels. The importance of the domestic oil burner to the petroleum industry is demonstrated by the fact that each burner will consume annually a volume of fuel equal to that consumed by four automobiles.

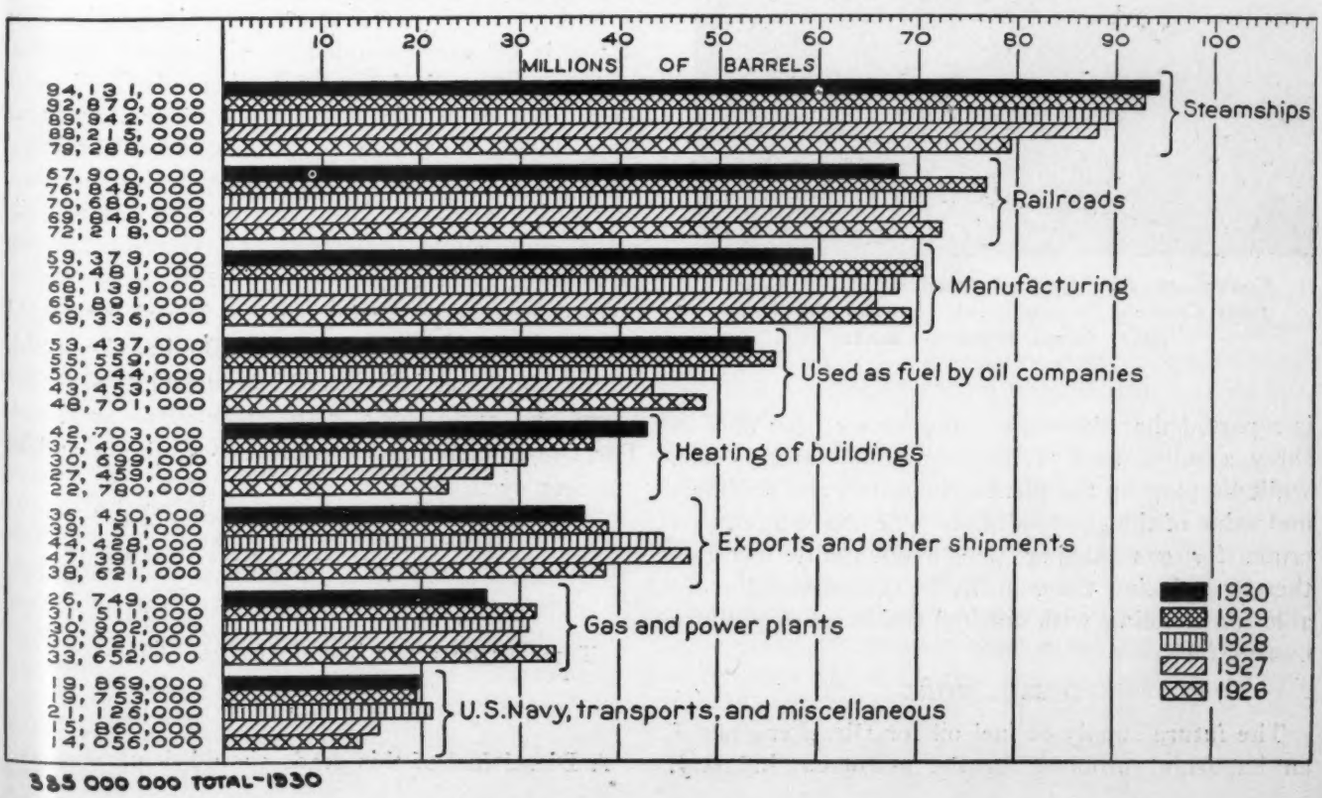
From the same distillate fuel oil tank the refiner must furnish fuel for two other purposes, namely, gas oil for the manufacture of carburetted water gas and fuel for Diesel engines. Both of these users of gas oil recognize that the market price of this product fluctuates with gasoline prices and are anxious to develop other products for their particular needs.

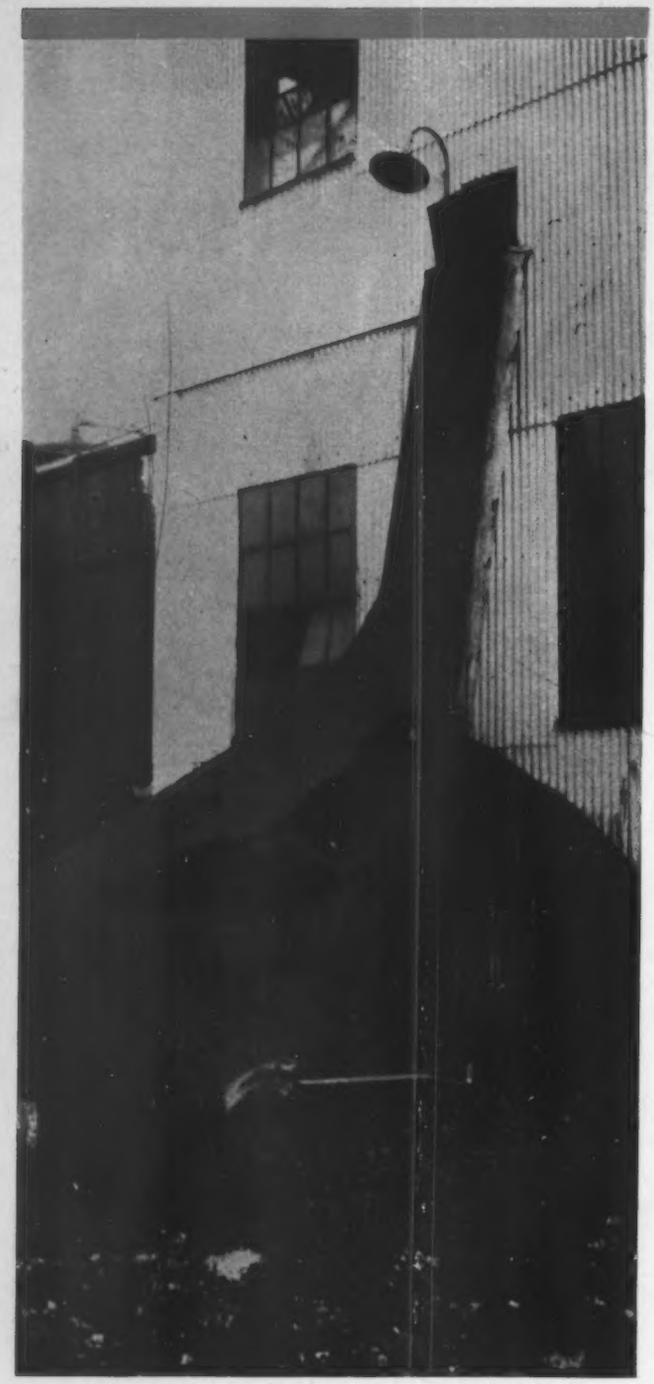
FUEL FOR GAS PRODUCTION

The total volume of carburetting oil used in the manufacture of water gas in 1931 is estimated to be about 600,000,000 gallons.[1] For some time past some eastern seaboard gas plants have been operating on a "high coke-residua oil." The material used is a topped crude having a coke residue of not over eight per cent. One seaboard gas plant consumed a million barrels of refinery residual oil in a year. It

[1] P. T. Dashiell, Report, A. P. I. Meeting, Tulsa, June 1-3, 1932, p. 39.

Gas Oil and Fuel Oil Deliveries by Uses, 1926-1930





Continuous Discharge of "Carbon" Filter Cake from Goodwin Process Plant, Imperial Oil Company, Sarnia, Ontario, Canada.

is reported that these gas makers have been able to show a substantial saving in manufacturing costs, while keeping up the plant throughput and the thermal value of the gas produced. The use of a reduced crude for gas making will undoubtedly increase, thereby reducing the quantity of this material available for blending with cracked residuum to produce bunker fuels.

DIESEL FUEL

The future supply of fuel oil for Diesel engines is an important problem for the petroleum industry. This could be restated to read, a supply of lower priced fuel oil for the Diesel engine is of utmost importance to both the engine manufacturer and the user. The use of Diesel engines for both marine and stationary service has increased very rapidly in the past few years, so that their fuel supply, when gas oil is used, has brought them into competition with charge stock to cracking operations. The future of the Diesel engine will depend on the use of residual fuels if they are to compete with the modern steam installations.

The biggest single obstacle in the path of the expansion of the use of Diesel engines is the unfavorable ratio of the price of suitable fuel oil to the price of boiler oil. What is known as "Diesel fuel oil" today sells for $1.60 per barrel at terminals in the New York harbor; boiler oil sells for $0.85. It is easy to see that the motorship bunkering in New York is at a great disadvantage. Admitting that with motorships 0.37 pounds of fuel per Bhp. is becoming the rule rather than the exception, the fact must not be overlooked that 0.60 pounds is also in the cards for steamers, making the following rates:

0.37 x $1.60 = $.59 motorship
0.60 x $ .85 = .51 steamer

The use of cracked residua opens up an entirely new field for Diesel fuel. It has been found that when an ordinary cracked residuum—say 10° A. P. I.—is blended with 20-30 per cent cycle stock and stabilized by the Goodwin Process, a very satisfactory Diesel fuel is produced. Such a fuel has been burned under commercial conditions. This fuel has been used in more than 20 different makes of Diesel engines in both this country and Europe, and ranging in horsepower from 15 to 3000. This heavier type of fuel is not recommended for high speed Diesels—of 500 r.p.m. and above—and where the load averages less than 50 per cent. A Diesel fuel produced from stabilized cracked residua has several desirable physical properties, such as high flash, slow burning, lubricating qualities, low pour, low B. S. and sediment, and from the consumer's viewpoint, more pounds per gallon.

The cost for producing such a Diesel fuel could be calculated as follows: Assume Bunker C or residuum at $0.85 per barrel, and Diesel fuel at $1.60 per barrel and cycle stock at the same value as Diesel. For Diesel blend use 70 per cent residuum and 30 per cent cycle stock.

$0.85 x 70 =	0.595
$1.60 x 30 =	0.480
	$1.075
Treating cost per barrel charge	.065
Total	$1.140

A Diesel fuel of this grade should demand a mar-

ket price of at least the average between Bunker C and the present type of Diesel.

ROAD OIL

Another use for cracked residua, which is growing, is for road oils. Soon after cracking was introduced in the oil industry it was found that cracked residuum was an improvement over straight run bottoms for use as a road oil. Specifications were soon imposed on road oils, requiring the use of cracked residua. These must be low in B. S. and sediment on account of the solubility tests imposed in most states. Some states require high solubility in carbon disulphides; carbon tetrachloride or benzol.

Morell and Egloff[2] outline a method for producing a specification road oil from the liquid residue of the cracking process. They refer particularly to the production of road oils from the liquid residue of the cracking process referred to as "flashing." They state, "One of the results of the flashing operation is the reduction of suspended carbonaceous or pitching material in the residue. This is quite important in road oil making as well as in the production of a marketable fuel oil." By operating the cracking process in a different manner a greater yield of naphtha can be produced, but the residuum will contain a greater per cent of B. S. and sediment.

The residuum described in the second paragraph below, was produced by more intensive cracking and contains 7.5 per cent B. S. and 2.8 per cent sediment, so that it does not pass specifications for either fuel oil or road oil. The blending tests outlined below demonstrate that the residumm after treatment by the Goodwin Process, will meet the ordinary specifications for both of these services.

BLENDS—CRACKED RESIDUA AND DISTILLATE PRODUCTS

A number of refiners are marketing their residua as fuel oil after adding up to 50 per cent of pressure distillate bottoms, cycle stock or gas oil. In most cases this procedure is not economical because the blending stock added has a market value as domestic or industrial fuel considerably higher than that of the blended fuel oil. In many cases the refiner finds that the addition of a distillate product to a cracked residua produces an excessive amount of "carbon." Most of this precipitated "carbon" is very finely divided so it cannot be removed by short time settling, and the filter rate is very low. Several factors affect the quantity of "carbon" precipitated, especially the amount and type of blending stock used. This can be demonstrated by the following data.

Samples of cracked residuum were blended with equal volumes of different solvents and petroleum products and the mixture centrifuged in regular ASTM tubes and the volume of solids determined.

[2]National Petroleum News, April 15, 1931, p. 59.

Table I—Residuum—Solvent Blends

Solvent	Before Treatment	After Treatment by the Goodwin Process
Benzine (30-75° C.B.P.)	34.0 per cent	4.0 per cent B.S.
Carbon tetrachloride	2.72 per cent	0.13 per cent B.S.
Benzol	7.50 per cent	0.40 per cent B.S.
Benzol-Sediment Extraction	2.82 per cent	0.07 per cent Sediment

The original residuum had the following inspection:

Gravity.....10.5° A. P. I.
Viscosity .....142 sec. Furol at 122°F.
B. S.....7.5%
Sediment.....2.8%

When the above residuum was treated by the Goodwin Process more than 30 pounds of "carbon" were removed per barrel treated. The processed oil showed 0.4 per cent B. S. and 0.07 per cent sediment. Equal volumes of the following solvents and blend stocks were added to both the treated and untreated material and the amount of "carbon" precipitated determined by centrifuged tubes.

The processed sample described above, even though it shows only 0.4 per cent B. S. and 0.07 per cent sediment by the standard testing methods, will give varying amounts of "carbon" precipitation, depending on the type of petroleum distillate or solvent used for blending. This fact is demonstrated by the solvent blends described above, and the treated residuum blends with different petroleum distillates outlined below. These same petroleum distillates, when blended with an unstabilized residuum, would precipitate much greater percentages of solids.

Table II—Residuum—Petroleum Distillate Blends

Blend Stock	A.P.I. Gravity	Per Cent Sed. By Centrifuge	A.P.I. Gravity-Blend
Pressure Distillate Bottom	30°	7.0	23°
Furnace Fuel Oil (uncracked)	35°	24.0	25°
Cycle Stock	21.8°	0.2	18°
Dist. from C. C. Residuum	21.4°	0.5	17.9°

Some refiners market their blended fuel oil on gravity specifications believing that a certain gravity blend will give a satisfactory product. The above blends demonstrate the fallacy of such reasoning, because the highest gravity blend gave the greatest amount of "carbon" precipitation. In making such blends the minimum of "carbon" will be precipitated if a thoroughly cracked product is used for blending and the gravity of the blend stock is kept as near as practicable to the gravity of the residuum. Some attempts have been made to filter the residuum after blending with a distillate product, but have always resulted in failure because the fine "carbon" reduces the throughput of the filter to an uneconomical rate, after a few minutes operation.

By utilizing the Goodwin Process a stabilized fuel can be produced from the cracked residua, either before or after blending with a distillate product. A plant has been operated to produce a 11° A.P.I. finished product from residua produced in several different cracking coils. The gravity of the residua

varies from hour to hour but the light oil is automatically added to give the desired gravity blend. The added distillate reduces the viscosity and increases the A. P. I. gravity so the flocculated carbon is more easily removed by either gravity settling or filtration.

CHANGES IN DEMAND FOR FUEL OILS

The past few months have brought a very definite change in the type of bunker fuel oil demanded from the refiner. The tendency is toward a product of much lower viscosity than that of Bunker C (300 Furol Viscosity at 122°F). For this change in demand there are two reasons: first, much of the fuel supplied was almost a solid at ordinary temperatures and required heating before being pumped, and second, the heavy fuel often contained suspended solids which settled out when the oil was heated. Another factor in favor of a low viscosity product is its decreased tendency to emulsify.

Bids which were opened recently for the United States Navy's bunker fuel oil requirements for 1931-1932 certainly demonstrate this demand for a lower viscosity product. Their bids for the West Coast called for 4,921,000 barrels of Bunker B grade (100 viscosity Furol at 122°F) and excluded entirely the Bunker C grade. For the East Coast and Gulf ports the bids covered 2,688,800 barrels of Bunker A grade (100 seconds viscosity at 77°F. approx. 30′ at 122°F.) and only 935,500 barrels of Bunker C grade. In other words, in the Navy demand totalling 8,545,300 barrels of bunker fuel oil only 10.94 per cent was for Bunker C grade.

In the Gulf Coast district this demand for a lower viscosity fuel is being met by supplying a topped crude. Such a procedure is economical solely because of the extremely low market price of crudes in this district. In other districts, such as the West Coast, much of the demand is supplied from cracked residuum and topped crude to which is added an overhead product. A more economical procedure would be to operate the cracking units to produce a 100-second viscosity residuum, then stabilize. This would eliminate the use of both reduced crude, which could otherwise be used for charge to cracking units, and overhead distillate, which has a higher market value than bunker fuel.

The current fuel oil for the Navy's Pacific Coast requirements from July 1, 1932, to June 30, 1933, is being furnished largely by the concern which was successful bidder on 4,949,500 barrels out of a total of 5,211,500 barrels. Fuel oil on this new contract is of a "modified" Bunker B specification, with 17° A. P. I. as the minimum gravity. This gravity limitation practically eliminated the use of a cracked residua and resulted in higher prices. It can be readily realized that the price will continue to increase for Navy fuels if their specifications make it possible to use only reduced crude. When used as charge stock in modern cracking equipment, this reduced crude has a naphtha value which would make it uneconomical for fuel oil use. Perhaps the best method for producing a Bunker B fuel of 17° A. P. I. gravity would be by means of a viscosity-breaking unit. Such a method would give a lower naphtha yield when compared with the modern higher pressure cracking units.

Since cracking was first introduced into the petroleum industry cracked residua have been used for fuel oils, but usually after blending with either a reduced crude or distillate, or a mixture of two. The use of these cracked residues for fuel oil has developed special problems, the most important of which is the deposition of solid "carbon" in refinery tanks, consumers tanks, lines, valves and burners.

DIFFICULTIES IN THE BURNING OF CRACKED FUELS

These problems in burning such fuels formed the subject of a recent meeting of the American Society of Mechanical Engineers in New York City. The principal paper was read by T. B. Stillman of Babcock and Wilcox Company. The subject of the paper was "Problems in Utilizing Bunker 'C' Fuel Oil With Special Emphasis on Oils Containing Cracked Residues From High Pressure Stills". This paper was discussed by a number of men interested in the design of burners, design of boilers, as well as by producers of fuel oils, and a number of consumers, including the United States Navy.

Much of the discussion covered the difficulties encountered with cracked fuels for marine use, for it is recognized that in this service the conditions exacted are usually more severe. It was pointed out that a vessel has a large number of small tanks for fuel storage and the number increases up to more than 200 for fighting ships. It can be readily realized that if a fuel oil precipitates solids, tank cleaning soon becomes a serious problem. The Navy has recognized this problem and is doing extensive research work at the Fuel Oil Testing Plant, Navy Yards, Philadelphia, and at the Naval Research Laboratory, Washington, D. C.

Some criticism was raised against the present methods for testing fuel oil, such as B. S. by centrifuging (A. S. T. M. Method D-96) and "Sediment by Benzol Extraction", Method 300-2. These tests do not fully show the presence of unstable hydrocarbons which later form deposited solids to give operating difficulties. It is suggested that a stability test be formulated based upon the treatment of the fuel oil sample with about 0.5 per cent by volume of dilute sulfuric acid, since such a test would give some indication as to the source and stability of the fuel.

FAVORABLE PHYSICAL PROPERTIES OF CRACKED FUELS

A fuel made by stabilizing residua makes an ideal product for marine and commercial burners. Such

a fuel has a low viscosity for a given gravity, and has a low pour—in fact usually pours at zero. The low pour and viscosity of the oil are especially favored for marine fuel, because it requires a low pre-heat prior to pumping and burning, and a smaller amount of steam is necessary for atomizing burners.

This property of low viscosity at ordinary temperatures so that it is not necessary to use a high pre-heat for firing.

Viscosity Furol	Viscosity Change per Degree F.
at 100°F — 210 sec.	
at 122°F — 83 sec.	10 sec.
at 150°F — 37 sec.	1.8 sec.
at 200°F — 14 sec.	0.46 sec.

It is a valuable aid in using a cracked residua fuel to have the refiner furnish the viscosity at two temperatures and then through these two reference points, to draw a line to represent the temperature-viscosity. It is advisable to keep the firing temperatures down to a minimum for successful operation.

There exist in cracked fuel two materials which cause difficulty in storage and in burning. The first are the solids which exist in the oil as actual solids, and the second are unstable hydrocarbons which decompose to form additional insoluble solids. A general statement can be made to the effect that when gasoline is produced by cracking, a certain amount of carbon and potential carbon-forming materials will be produced. These carbon materials will either be deposited in the cracking units or will be removed from the cracking unit in the residuum. An idea as to the quantity of potential carbon in the residuum can be gained from the fact that in operating a cracking unit to produce coke as a final product, rather than as a liquid residuum, there is produced up to 100 pounds of coke per barrel of oil charged to the unit.

These two "carbon" materials cause difficulties to both the refiner and the consumer unless they are kept low by limiting the cracking or else are removed from the residuum after it leaves the cracking unit. It is of interest to note that the material which is called carbon is not actually 100 per cent carbon, but contains from 86 to 90 per cent carbon; so that in reality, it is essentially a high-carbon hydrocarbon.

THE GOODWIN PROCESS

The Goodwin Process* was developed to overcome the difficulties encountered in marketing cracked residuum in its natural condition, due to the precipitation of solids in transit and in storage. Some of the solids are present in the residuum as it comes from the cracking units, but many of the difficulties are caused by the unstable materials which decompose to form more settling solids and consequently increase the B.S. and sediment.

The process consists of special chemical and mechanical treatment of the residuum. It yields, as end-products, two materials of value—a stabilized fuel oil, marketable as A, B or C grade, depending upon the viscosity, etc. of residuum, and a "carbon" suitable for local burning either as a solid or liquid fuel.

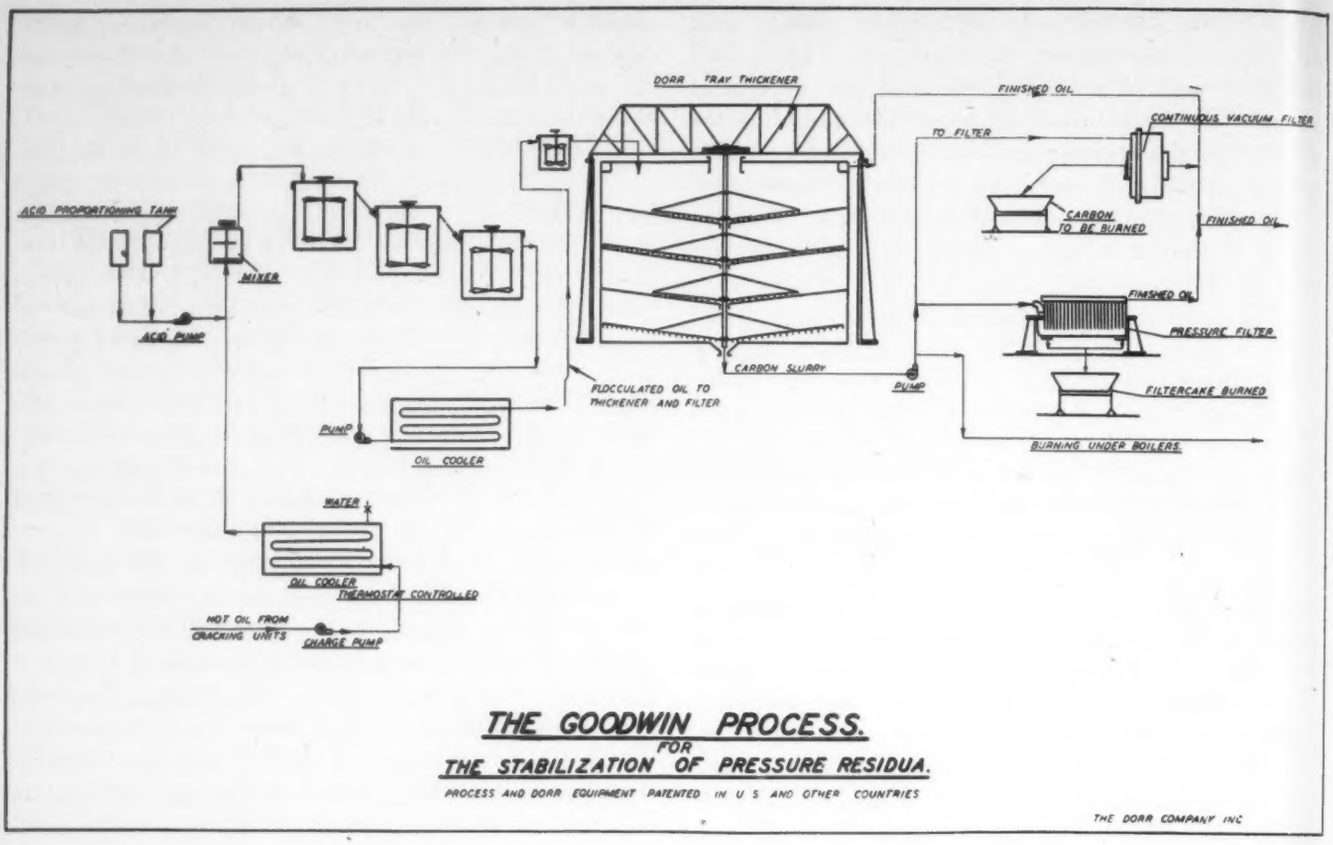
The addition of dilute sulphuric acid under regulated conditions modifies the unstable hydrocarbons in the residua, causing them to be precipitated and flocculated in a form suitable for separation. As a result of such treatment the modified solids can be removed from the oil by gravity settling or by filtration, leaving a permanently clarified, stabilized oil entirely suited to the market specifications for Bunker C or a higher grade fuel. This reaction, while undoubtedly complex, seems to be chiefly polymerization and can be largely controlled by maintaining proper conditions of temperature, strength of reagent, quantity of reagent, mixing and flocculation.

The accompanying diagrammatic flow sheet shows the successive steps in the treatment of the residuum and the relation of the various equipment units which constitute the process cycle. The process may be conveniently divided into four chief operations: (1) cooling the residuum to treating temperature, usually about 275°F; (2) acidulating with 30° Baume sulphuric acid and mixing thoroughly; (3) flocculation of the precipitated "carbon" in slow speed flocculators; and (4) separation of flocculated carbon by means of gravity in a thickener or by filtration.

The residuum usually leaves the cracking unit at a temperature of 600-650°F. so it is passed through a cooler to bring temperature to about 275°F. The acidulating reagent, which is spent acid from the refinery, is then added to the oil at a definite rate, followed by complete mixing. The acidulated oil is then charged into flocculators, usually three in number, which are arranged in series so that the oil is given a definite retention period, usually about four hours being required. The discharge from the last flocculator in this series, consisting of flocs of carbonaceous and inorganic matter (if lime is used in cracking charge stock), suspended in the stabilized oil, is pumped to a multi-compartment tray thickener. The thickener overflow is the stabilized fuel, which contains low percentages of B.S. and sediment and remains constant in storage. The carbon slurry from the bottom of the thickener contains from 20 to 50 per cent solids and is burned, as such, in the refinery or filtered to obtain a solid filter cake and an additional yield of stabilized oil from the filtrate.

In the case of some residua, especially high viscosity products, the oil is run from the last flocculator through a cooler to a suitable filter. In such cases the filtrate is the stabilized fuel and the "carbon" filter cake is a solid fuel suitable for local burning. It is of interest to note that the filter rate for a flocculated oil is several times that of an unflocculated product. The carbon filter cake can be burned in the refinery with coal or coke or can be

* Refiner, Feb. 1932, P. 188.



THE GOODWIN PROCESS.
FOR
THE STABILIZATION OF PRESSURE RESIDUA.

PROCESS AND DORR EQUIPMENT PATENTED IN U. S. AND OTHER COUNTRIES

THE DORR COMPANY INC

liquefied or fluxed at about 300°F. and burned as a liquid fuel. There is no loss in the process, for only two products are produced, namely, stabilized fuel for marketing and a solid carbon for local burning. This process removes from five to 35 pounds of carbon from each barrel treated, depending, of course, on the source of the residuum.

In a plant with a rated capacity of 2500 barrels per day at the refinery of Imperial Oil Refineries, Ltd., Sarnia, Ontario, the yield of stabilized fuel is 97 per cent, with the balance a solid "carbon" filter cake. The equipment necessary to carry out the process is outlined in the flow diagram. The total erected cost for a plant to process 1500 barrels per day would cost from $55,000 to $65,000, depending on local conditions. The cost of equipment decreases materially per barrel charged for larger capacities. The total treating cost, including reagent, labor, power, upkeep, interest, amortization, would be from 5.5 to 6.8 cents per barrel.

The Goodwin Process has a direct application to the solution of several refinery problems usually associated with cracking operations, such as the production of a low viscosity fuel oil by stabilizing cracked residua, the elimination of excessive B.S. and sediment which permits increase of gasoline yield by more intensive cracking, and from a marketing viewpoint it is possible to provide a number of different specification fuels by properly blending stabilized residuum. The use of the process also permits the unrestricted use of lime to reduce corrosion in the cracking equipment since the lime-sulphur compounds so produced are removed along with the carbonaceous matter.

CONCLUSION

The refiner should produce a clean fuel oil, thereby reducing service costs and sales resistance and not depend on the removal of solids by the consumer by means of strainers, filters, centrifuges, settling, etc. The refiner can produce a fuel oil from cracked residuum which will be "stable" or free from depositing solids during storage and use. Such a fuel oil from cracked residuum would have several physical properties superior to an uncracked product and some day the consumer will demand a fuel produced entirely from cracked residuum.

This statement can be amplified by an example. A few years ago, when cracking equipment was first installed in the refineries, a number of the consumers of gasoline in this country, and practically all of the consumers in Europe, formulated specifications which would eliminate cracked gasoline, because they believed that such a product formed gum and an excess of carbon in their engines. The art of refining is now so developed that the objectionable features are eliminated, either by the method of cracking or by subsequent treatment. Today most of the gasoline specifications have requirements that make it difficult to meet them with anything but a cracked product. This example certainly demonstrates that a product which is considered of poor quality today can be changed by chemical and mechanical treatment to a product which will be of high quality and in universal demand tomorrow.

Vacuum Stills *In the Manufacture of* Asphalt

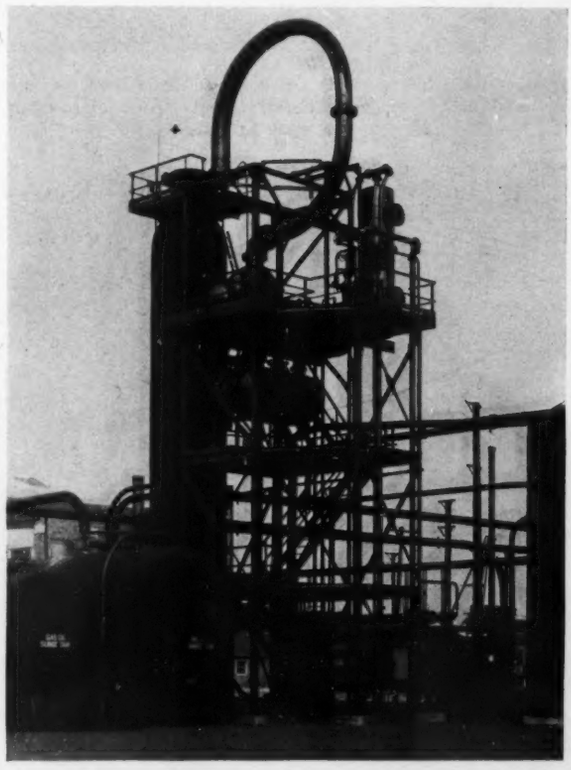
JOHN C. GLENN
Foster Wheeler Corporation

ASPHALT may be derived from several different sources and may be manufactured by several different processes. During the past couple of years Foster Wheeler Corporation has installed eight different distillation units designed primarily for the manufacture of asphalt. Five different types of single-stage and two-stage units have been used due to different base products from which the asphalt was derived and due to different conditions peculiar to the refineries in which the installations were made.

Raw products for asphalt manufacture, as used in these distillation units, include light crude, heavy crude, reduced crude and cracking stock residuum. The output of the units varies from a maximum of 1000 barrels per day in the smallest unit to a maximum of 14,000 barrels in the largest units.

It is obvious that a unit handling 1000 barrels of cracking still residuum would be greatly different from the unit processing 14,000 barrels of Venezuelan crude per day, even though the principal product of each unit is a high grade asphalt. An important factor which influences the design of an asphalt unit is degree of flexibility desired. This is in turn dependent upon the estimated permanence of the market, both the crude and the finished products.

A comparison of the eight units mentioned above is of interest to a refinery engineer, even though he is not interested in asphalt products. The same controlling features which determine the selection of asphalt equipment will also influence the selection of distillation equipment for the manufacture of other products. This is especially true inasmuch as no single product can be made independent of other products, that is, the manufacture of asphalt creates one or more by-products, such as cracking stock, lubricating oil or light fractions. Conversely, the manufacture of lubricating oil creates various by-products, sometimes including asphalt.

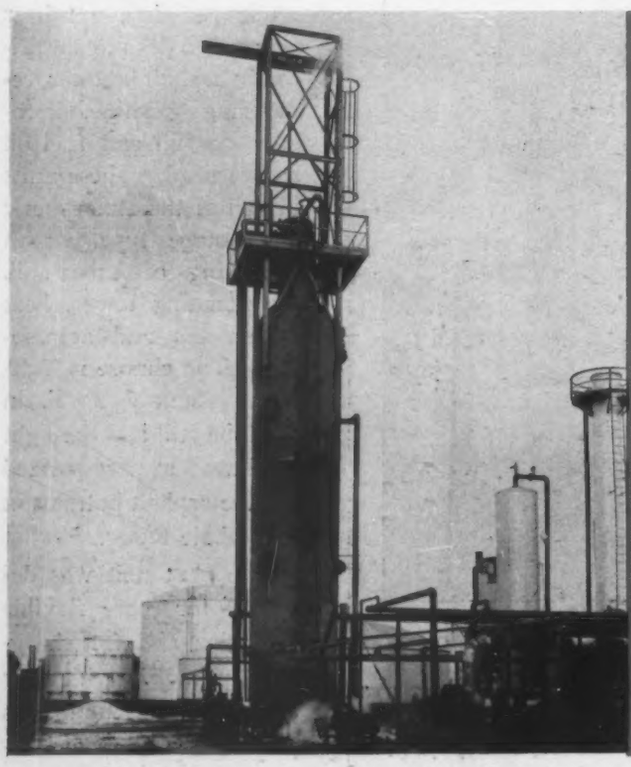


Vacuum flash jug used to produce a specification asphalt from cracking still residue. In addition to the asphalt a considerable quantity of recycle stock is also obtained. This unit uses no fuel, except the small amount burned in a separately fired process steam superheater.

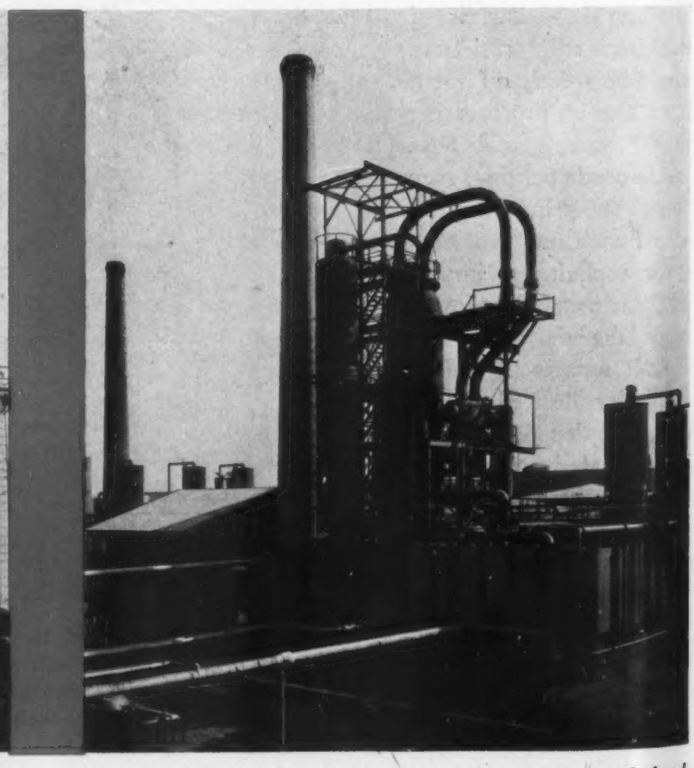
The first three of the eight asphalt units mentioned above were installed in an Eastern refinery. These three units charge a total of 16,000 barrels of Venezuelan crude per day, which is reduced to desired specification asphalt bottoms, recovering gasoline, kerosene, gas oil and fuel oil as overhead. These units are all of the atmospheric single-stage type, each consisting of tube still, fractionating tower, heat exchangers and accessories. The charge is heated to about 700° F. in the tube still and the light products are vaporized off the asphalt bottoms in the bubble tower.

The next unit was designed for more flexible operation and for charging primarily heavy crudes. The unit was placed in a Southern refinery and charges as much as 14,000 barrels of

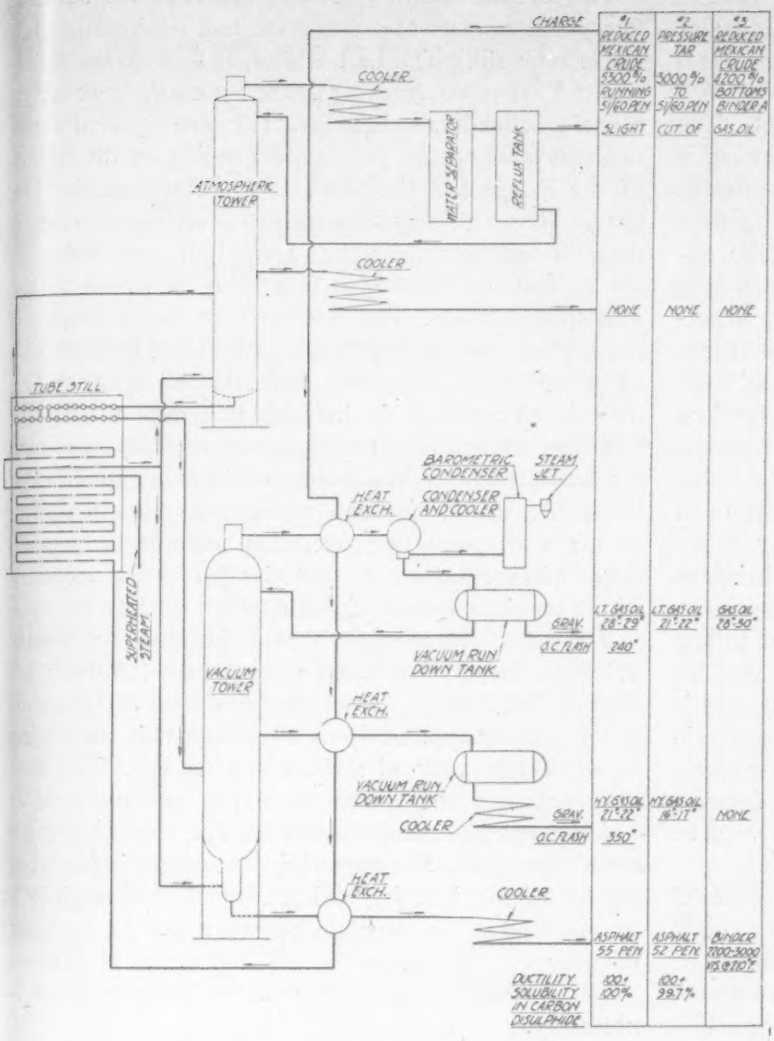
Two-stage atmospheric-vacuum distillation unit in a large Southern refinery. The crudes which it has fractionated to heavy asphalt bottoms include those from Colombia, Mid-Continent, Mexico, Venezuela and Louisiana.



Vacuum flash jug designed to separate cracking still residuum into recycle stock and asphalt without the use of an oil heater or any process steam. Separation is accomplished by high vacuum. The vapor condenser is located in the top of the tower to reduce to a minimum the pressure loss between the tower and the steam jets.



Two-stage atmospheric-vacuum distillation unit in an Eastern Seaboard refinery. This unit, which is complete with atmospheric and vacuum tube stills and towers, is designed to operate either as an asphalt unit or as a lube oil unit.

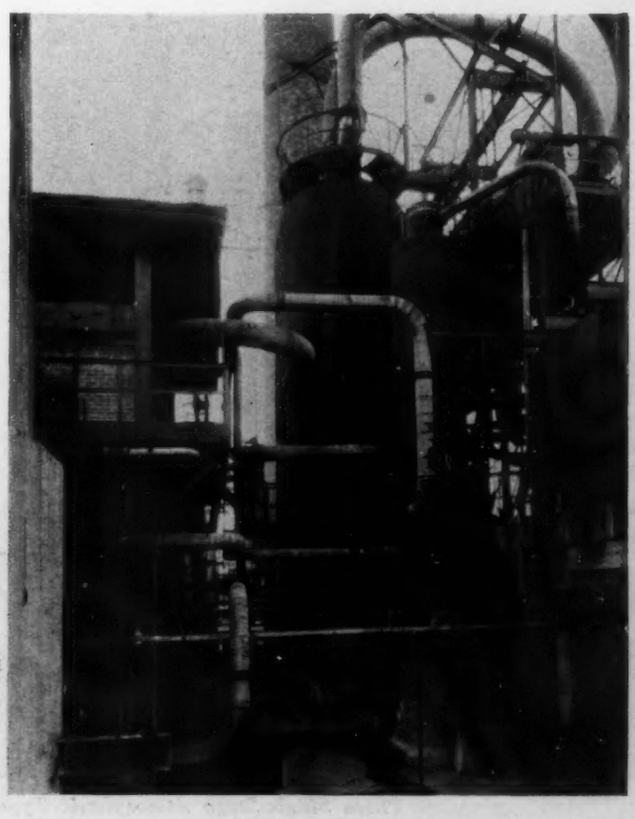


Flow diagram of two-stage distillation unit in New England. This distillation unit has a single tube still which supplies heat for both the atmospheric and vacuum fractionating towers.

Two-stage atmospheric-vacuum distillation unit in a New England refinery. This unit although equipped with atmospheric and vacuum fractionating towers has only a single tube still. It is designed to charge heavy crudes or reduced crudes to recover a maximum yield of specification asphalt. The accompanying flow diagram shows the arrangement of the equipment.

crude per day. Many different kinds of crude have been run through the unit successfully, including those from Colombia, Mid-Continent, Mexico, Venezuela and Louisiana. The unit is of the two-stage type, consisting of atmospheric and vacuum tube stills, atmospheric and vacuum fractionating towers, heat exchangers and accessories for both atmospheric and vacuum stages. Work of fractionation is divided about equally between the two stages, although the vacuum fractionating tower is larger, due to the increased volume of the vapors at low pressure. Products recovered from this unit vary as widely as the charges themselves. High grade lube stocks are recovered as overhead from practically all charges and the asphalt bottoms vary from less than six per cent with Mid-Continent crude to almost 50 per cent with Lago crude.

The fifth asphalt unit was installed in a Great Lakes refinery for the processing of cracking plant residuum. This unit consists of a vacuum flash jug, together with heat exchangers, condensers and other accessory equipment, but does not include a tube still. Residuum is received from a cracking unit at the rate of 1000 barrels per day and is pumped into the vacuum flash jug, while still hot. With the aid of highly superheated process steam the residue is stripped of all the lighter products, leaving only a salable asphalt. The lighter



products are condensed and used as a recycle stock. The asphalt is pumped out of the flash jug in a continuous stream. This flash jug thus produces a satisfactory recycle stock and a salable asphalt out of a product which previously had no value except for use as fuel. The chief advantage of such a system is that no heating is required except for the exhaust steam used for process.

The sixth asphalt unit was installed in an Eastern Seaboard refinery where it charges heavy crudes, reduced crudes, or cracking still residuum. The unit is of the two-stage atmospheric vacuum type with a normal throughput of 3500 barrels per day for asphalt production. The same unit is designed so that Mid-Continent crude may be run at the same rate to produce maximum yield of overhead lubricating stock. Asphalts and binders have been successfully run to practically any desired specification. Charges so far put through this two-stage unit include 12° A.P.I. gravity heavy Mexican crude, 13.6° A.P.I. gravity heavy Mexican fuel oil, 14.3° A.P.I. gravity reduced Venezuelan crude, and 9.0° A.P.I. gravity cracking residue from Luling crude. The by-products from asphalt manufacture include naphtha, gas oil and fuel oil. The raw charge is pumped through heat exchangers and the atmospheric tube still, entering the atmospheric fractionating tower at a temperature of approximately 500° F. Bottoms from the atmospheric tower pass through the vacuum still reaching a final desired temperature of approximately 600 to 750° F. Considerable heat is recovered by the heat exchangers, the charge being heated to 400° F. when asphalt is being manufactured. On the other hand when Mid-Continent crude is run to overhead lube stock, 320° F. is reached in the heat exchangers.

The seventh unit was installed in a New England refinery and consists of a two-stage unit equipped with a single tube still. The unit is designed to charge either reduced crude or cracking stock residuum, recovering asphalts or binders as bottoms. The capacity of the unit is about 5000 barrels per day, depending on the nature of the charge and the products to be recovered. The charge passes through the entire convection section of the still and then through a few of the roof tubes in the radiant heat section before being delivered to the atmospheric tower. The bottoms from the atmospheric stage pass through the balance of the radiant section of the still into the vacuum tower. With heavier crudes or reduced crudes it is desirable to reduce the lighter fractions under atmospheric pressure in order to reduce the amount of process steam required in the vacuum stage. The use of two towers gives maximum flexibility to the unit, permitting operation under a very wide range of charging stocks and also permitting recovery of the maximum yield of marketable products.

The most recent asphalt unit installed by Foster Wheeler Corporation is a flash jug in a Southern refinery. This flash jug is designed to charge 3000 barrels per day of hot residue from a cracking unit recovering recycle stock overhead and asphalt bottoms. This unit does not heat the charge since the low pressure at which it operates makes further heating unnecessary for clean separation. The vapor heat exchanger is placed in the top of the flash jug and pressure loss through it is so small that an absolute pressure of 25 mm. of mercury can be obtained at the bottom of the tower. With this low operating pressure no process steam is necessary.

Three Single-Stage Atmospheric Type Asphalt Units in an Eastern Refinery.

FORMATION *of* Coke in the Cracking Operation . . .

A. W. TRUSTY
Chief Chemist
Louisiana Oil Refining Corp.

THE refiner of petroleum always has for his aim the production of the maximum amount of gasoline with the minimum amount of coke. Coke formation is the greatest source of the cracking unit's trouble. Split, burned and sagged cracking coil tubes, plugged tar lines, separators, etc., are usually caused by the accumulation of coke.

Some sales specifications for fuel oil are difficult to meet because of the presence of coke and heavy condensation products. The two per cent maximum BS & W by centrifuge specification is exceeded in some cracked fuel oils due to the presence of these compounds, coke, carboids, asphaltenes, etc., which are insoluble in cold benzol. The .25 per cent sediment specification in Bunker C fuel oil is sometimes exceeded in cracked fuel oils due to the presence of coke or carboids. This article deals with the formation of coke from the various cracking stocks and with the effect of temperature.

COMPOSITION OF COKE

A typical analysis of a sample of petroleum Coke:

Proximate Analysis

Moisture	.35%
Volatile matter	7.7
Fixed carbon	90.8
Ash	1.15
B.t.u./lb.	15490

Ultimate Analysis

Carbon	97.3
Hydrogen	1.2
Nitrogen	.2
Sulphur	1.0
Oxygen	.3

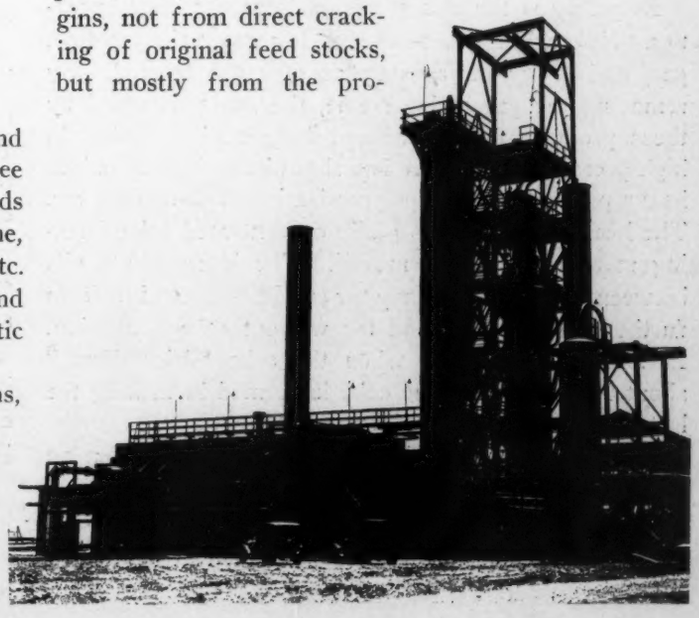
It is noted that coke is a solid rich in carbon and poor in hydrogen. A considerable part of coke is free carbon; however, there have been identified compounds such as picene, $C_{22}H_{14}$, crackene, $C_{24}H_{18}$, anthracene, $C_{14}H_{10}$, phenanthrene, $C_{14}H_{10}$, and chrysene, $C_{18}H_{12}$, etc. Soaker drum coke probably contains mostly gums and asphaltenes that consist of a highly condensed aromatic nuclei.

Light cracking of paraffins produces other paraffins, unsaturates and no coke. Aromatics are the worst coke formers of all the hydrocarbons, in fact the aromatics are considered to be the principal source of formation of coke and condensation products. The naphthenes dehydrogenate to form aromatics, which in turn, dehydrogenate to form condensation products and coke. The formation of coke or very heavy tars also takes place by the polymerization and condensation of compounds such as indene, C_9H_8, pentadiene, C_5H_8, etc.

In the presence of hydrogen, cracking reactions are carried out in quite a different direction than when hydrogen is absent. The coke formation and unsaturation is reduced when hydrogen is present. Under high pressure and in the presence of hydrogen and the proper catalyst there is no coke formation, the condensation products and coke being converted into lighter molecular weight hydrocarbons.

During the cracking operation, gasoline is formed as a primary decomposition of practically all of the heavy virgin hydrocarbons. At the same time, heavy condensation products are accumulating and when the yield of gasoline reaches a certain point, these heavy products begin to form coke rapidly.

The commercial cracking of an oil produces gas, gasoline, gas oil, tar and coke. The production of these products varies widely with different charging stocks, and conditions of temperature, etc. The cracking of kerosene produces much less coke than does the cracking of a heavy residue. In fact coke does not form unless cracking is carried beyond a certain definite point, and the formation begins, not from direct cracking of original feed stocks, but mostly from the pro-



gressive cracking of the secondary and tertiary reaction products formed from cracking of the original charging stocks.

Only a limited amount of gasoline can be formed in a single cracking operation without the formation of coke. Sachanen and Tilicheyev cracked Russian crude of 16.4° A.P.I. and obtained the following results.

Yield in Gasoline % by wt.	Coke % by wt.
6.1	.07
11.6	.11
21	1.06
25.6	4.92

A paraffin distillate of 28.7° A.P.I. was cracked:

Yield in Gasoline % by wt.	Coke % by wt.
14	0
21.5	0
34.2	.62

The coke formation sets in earlier when cracking heavy crudes or residues than when cracking kerosene or gas oils. From the work shown above, about 25 per cent gasoline can be made without the formation of coke when cracking a virgin gas oil while less than six per cent gasoline can be made on the heavy crude before coke formation sets in.

With some types of cracking units, for instance, those with large soaker drums, deep cracking takes place and a large amount of actual coke is formed. In other type units, for instance, a modern unit without a soaker drum, by spraying cold fresh feed in the vapor outlet line from the cracking coil, the cracking is stopped before the actual formation of coke sets in and only condensation products (heavy tar) is formed. The distillate yield in the latter case depends, of course, on the type of feed stock. For gas oils the yield is about 25 per cent and for heavy crudes or residues, about 5-10 per cent. The heavy condensation products are removed with the fuel oil and the secondary, tertiary, etc., products of cracking that have a boiling range between gasoline and fuel oil are recycled.

Recycling is the closest approach to the ideal operation of a cracking plant—that is, to remove the gasoline, gas, and heavy tar as soon as they are formed. By removing the gas and gasoline, the space occupied by these products can be utilized for cracking. Also, in high pressure units, there is a slight loss of gasoline into heavy products, due to polymerization of di-olefins, etc. The heavy tar, which is really concentrated coke forming material, is also removed. The intermediate oils between gasoline and heavy tar can be recracked to form further gasoline, gas and tar without coke formation. In a coking operation when the coke "dries down," about 90 per cent of the coke is formed in making the last five per cent of gasoline.

Most refiners, therefore, have to choose between an operation giving a high gasoline yield, low fuel oil yield and high coke yield, or an operation in which the gasoline yield is slightly sacrificed and the fuel oil production is increased, but the coke formation has been reduced to the point where sales specifications on fuel oil can be met and long runs are assured on the units.

DETERMINATION OF FREE CARBON (CARBOIDS)

About 10 grams of sample is placed in a dried, accurately weighed alundum thimble, the thimble placed in an extraction apparatus, and extracted with 90 per cent benzol until the solvent is clear. Dry the thimble at 220°F. and weigh.

DETERMINATION OF COKE FORMING CHARACTERISTICS OF FEED STOCK

The three laboratory tests, carbon residue, tar number and aniline number, if used in conjunction with each other, will give very definite data on the coke forming tendency of a feed stock. For method of determination of carbon residue, see U. S. Bulletin 323 B. The "Tar number" is made as follows: In a 100 c.c. graduated, glass-stoppered cylinder, put 50 c.c. of the feed stock to be tested, 50 c.c. of kerosene (as a diluent) and 10 c.c. of 93 per cent sulphuric acid. Shake for three minutes. Allow to stand for 1½ hours. Read the volume of tar that has separated out, subtract 10 c.c. for the acid originally added, and multiply by two. The tar number of a gas oil is 2—6, a heavy crude is 30—80, fuel oil is 100, etc. The lower the tar number and carbon residue, the lower the coke forming tendency of the feed stock.

The aniline number is determined as follows: In a test tube put 10 c.c. of the oil to be tested and 10 c.c. of aniline. Insert a thermometer and wire stirring coil. Immerse test tube in a water bath and heat bath slowly. Stir constantly and note the temperature at which the two liquids are miscible. A high aniline number, 170-185°F. indicates a paraffin base oil, which, if cracked moderately will form little coke. An aniline number of 130-160°F. indicates a naphthene base oil, which will have coke forming tendencies between a paraffin and aromatic base oil. An aniline number below 100°F. (aromatics are miscible in aniline at all temperatures) indicates an aromatic base oil which has the highest coke forming tendency of any of the hydrocarbons.

By use of these three tests, by consideration of the coke content (insoluble in hot benzol) of the fuel oil and of the BS&W (by centrifuge) content of the fuel oil, the refiner can better determine whether he is carrying the cracking reaction too far for most efficient operation, or whether the cracking reaction is not proceeding far enough for the ultimate conversion per pass.

Developments *in* Asphalt Processing

JAMES E. MOUL
General Manager, The Turbo-Mixer Corporation

PROGRESS in distillation has brought about marked economies in the production of asphalts from all types of asphalt bearing crudes. The vacuum flash coil has reduced the time of separation from 24 hours to a matter of a few minutes. Only recently, however, has technical development work tended to influence the degree of oxygen absorption, savings in air, better dispersion of air, savings in power, reduction of the time factor, and thus bringing about lower costs generally in the art of air blowing.

The old method of batch and continuous shell still distillation procedure in the production of asphalt limited the manufacture of such products to crudes high in asphalt content, such as Mexican and heavy California oils. The limitation was only one of economics and with the advent of the vacuum flash coil asphalts are produced economically from many crudes inherently low in asphalt content. Likewise, the new system is applied to manufacture of asphalts from cracking unit residues.

The flash vacuum coil now used for the separation of asphalts from crude permits instant cutting without damage to the residue. Light and heavy middle oils are fractionated from the heavy asphaltic residue in one operation, and the residue is further refined for the production of any desired consistency. (Refiner, Oct., 1931, page 80.) It is this further refining phase of the manufacture of asphalt products that but little progress has been made, until within the past year or two.

TRADITIONAL PRACTICE

The apparatus employed for oxidation or air blowing of asphalt, adopted many years ago when air blowing was a new art and becoming almost traditional practice, consisted of the horizontal shell still provided with a system of perforated pipes lying along the bottom of the shell. The agitator piping is placed so that the agitating air is directed against the still shell. Cross states that the amount of air and rate of blowing is usually about 300 cubic feet per barrel of oil per hour and for delivering air to an asphalt blowing still with the oil at a temperature of 400°F. and producing 250 barrels per day, 100 horsepower is required. (Kansas City Testing Laboratory, Bulletin 25, 1931, revised edition.) Recent investigation and research on the part of certain petroleum refining and roofing manufacturing companies, and The Turbo-Mixer Corporation, has resulted in the perfection of a new system of air blowing which markedly increases the efficiency of that phase of asphalt manufacture.

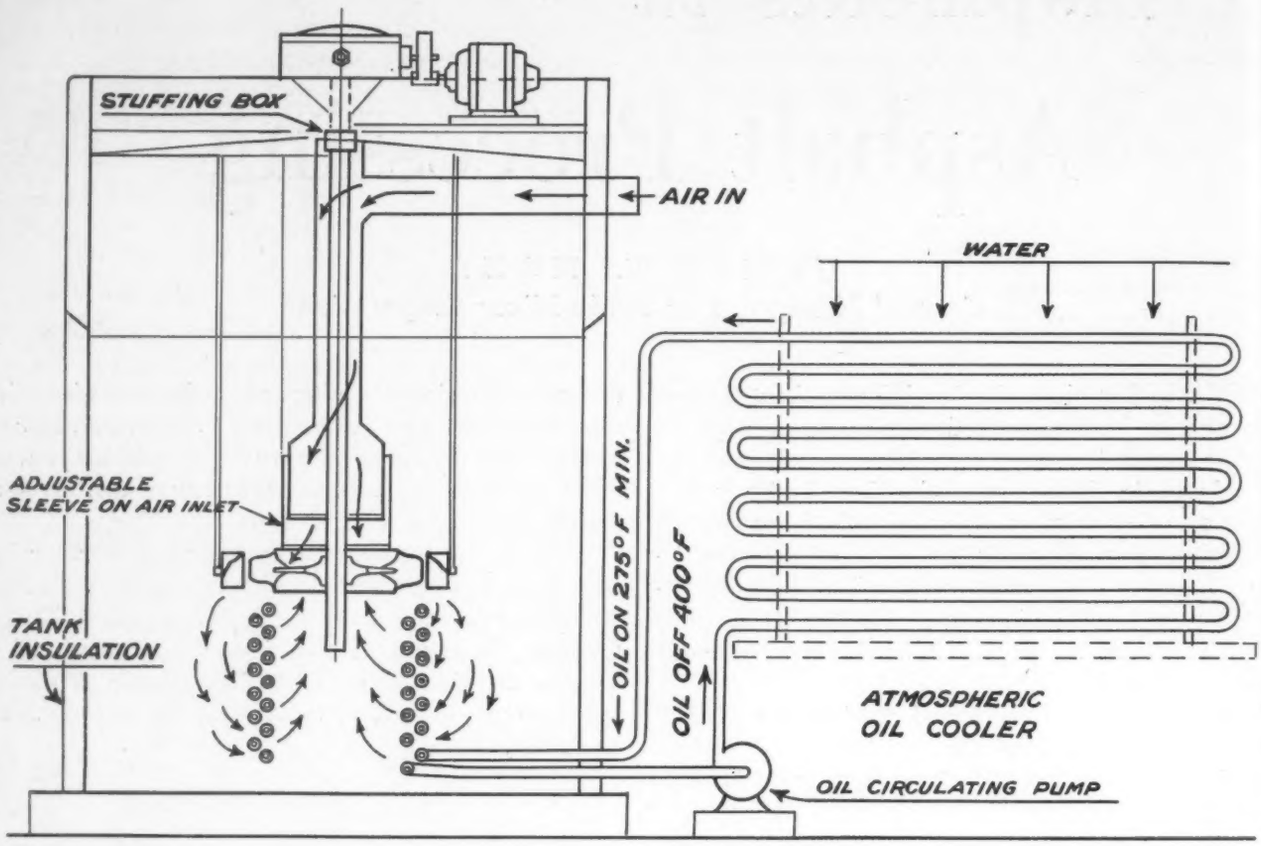
With the newly developed system of air-blowing important savings are effected which economies result from the ability of the mechanical device called Turbo-Oxidizer, to induce its own powerful air flow and to disperse this air in a very finely divided state, presenting much increased surface, throughout the asphalt under treatment.

FUMES LESS HAZARDOUS

Due to increased oxygen absorption savings of 50 to 90 per cent of the air formerly required are noted. Working with the new system the blowing cycle has been reduced one half to one third of the former time, which is reflected in increased output per still. With the oxidizers in service, which are low powered machines, the former blowers are no longer required. Because of the reduced air requirements the fume volume is reduced, with consequent reduction of fume losses. Further, because of the lower oxygen content, such fumes are less hazardous. In the new system "top steaming" is practically eliminated, effecting further savings through reduced steam consumption.

The oxidizing machinery or system, as shown in the accompanying flow chart, consists of a cylinder carrying air to the top of an efficient centrifugal impeller which sucks in a mixture of air and asphalt, discharging the mixture through curved deflecting blades at a velocity of 800 feet per minute, through the remainder of the asphalt. Due to the velocity and the scrubbing action secured, the air is broken into fine bubbles which are continually distorted by velocity changes, resulting in a greatly increased oxygen extraction. The power consumption is reported as about one fifth that required for power blowers, and where cooling is resorted to, a considerably greater speed of blowing is maintained.

For cooling, it is recommended that a system similar to that shown in the drawing be used. Cooling coils are supplied with oil which can be returned at a temperature which will insure freedom from congealed asphalt on the surface of the coils and so allow good heat



The Turbo-Mixer Oil Cooled Asphalt Blower

transfer. The use of cooling allows utmost speed to be realized in the blowing operation, and with the temperature held within safe limits, the quality of the asphalt produced is under constant control assuring production of the type of products desired. Existing tanks and stills are utilized, since the Turbo-Oxidizer is designed for installation in either vertical or horizontal vessels.

DUST MIXING

The dispersive power of the impeller makes it adaptable to the problems of filling asphalt. In one large refinery where asphalt is filled with slate dust an eight-hour cycle was previously required to mix 20,000 gallon batches of asphalt and slate dust to a 50 per cent slate content, which time cycle has been cut down to three hours through use of this equipment. The slate dust, or any other finely ground material, when fed into the agitated asphalt, is immediately pulled beneath the surface and into the impeller where it is practically "sprayed" in a horizontal plane through the asphalt. A few passes through the impeller are sufficient to break down any aggregates to original particle size. Throughout the operation the asphalt-solid mix is homogeneous and at no time is there a tendency for the filler material to settle out.

Another use for the device is that of forming asphalt emulsions, or mixing two immiscible liquids to form emulsions, such as asphalt and water. Here again the fineness of the break-up of one phase in the other determines the quality and stability of the final products. Other factors entering into this process which effect stability of the final emulsions are the types of stabilizing agents, proportions of materials, and the like. The field is complex, and the types of emulsions are numerous, but as an example of work being done, one large refinery is successfully producing asphalt-water emulsions in 20,000-gallon batches, in a fraction of the time formerly required.

CUT BACKS

Another adaptation is that of making asphalt cut backs. Because of the quickness of blending of two miscible liquids that is obtained, large quantities of asphalt can be cut back in a continuous system with a comparatively small mixer. For example, a 100-gallon machine can cut back and deliver 2000 gallons of material per minute; high viscosities being no handicap. The newly perfected system is therefore not only fitted for air-blowing but is adaptable in such work as emulsification, filling and cutting of asphalts.

REFINERY

Waste Water Recovery

A. C. EMBSHOFF

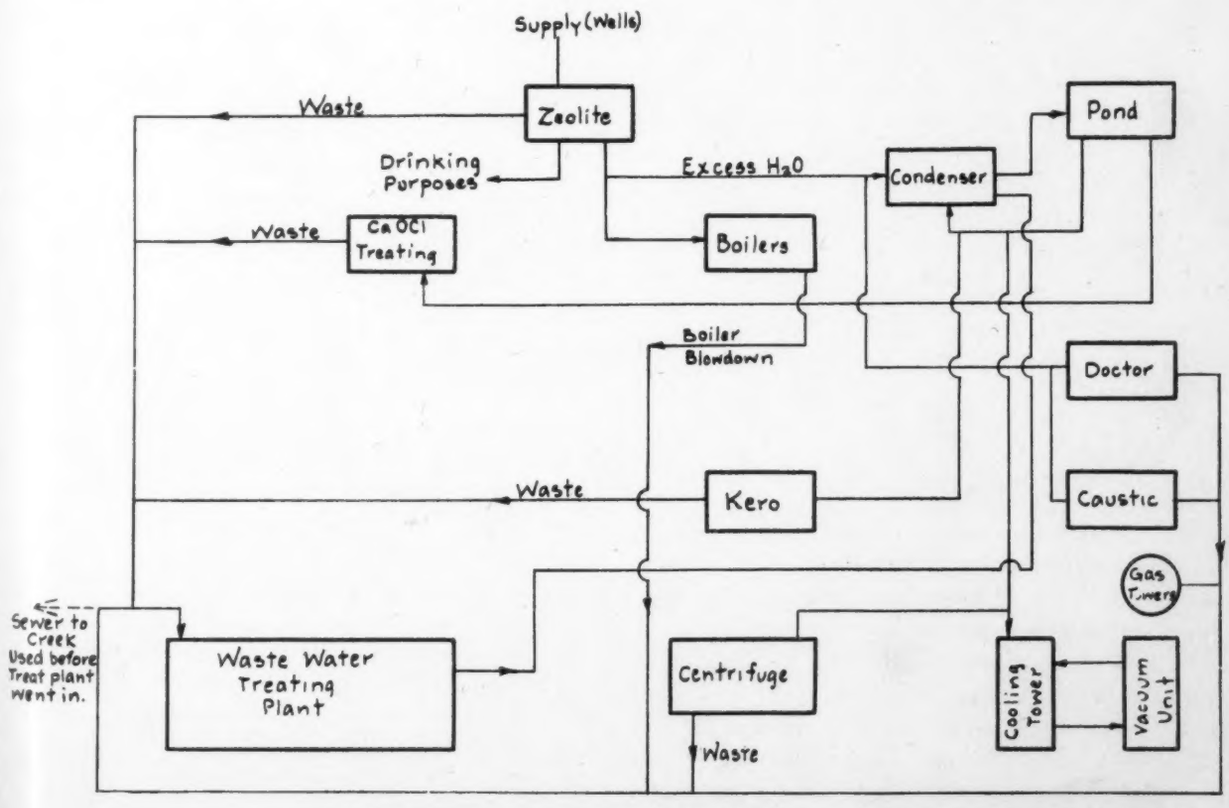
Chemical Engineer, International Filter Company

DOUBTLESS there are many refineries blessed with an abundant water supply obtainable at reasonable cost and with facilities for disposing of refinery wastes without serious contamination of the streams into which these wastes are discharged.

However, there are many others with an inadequate or expensive water supply; which, in addition, are faced with threatened litigation for contamination of the streams into which their wastes are discharged. To such plants, the matter of waste water recovery should be of great interest because by the installation of a properly designed waste water recovery treating plant, the total amount of fresh water required is materially reduced and contamination of public supplies is avoided by treatment and reuse of the water which would otherwise be wasted.

Typical of the latter class was a refinery in Northwestern Oklahoma which, in the spring of 1931, was faced with the need for more water to supply the heavy condensing requirements during the summer months; and with waste water pollution of a small nearby stream which occasioned considerable complaint from farmers using the water for stock. In fact, in a few cases, suits for damage for pollution had already been filed. The simplest solution would have been the drilling of a new water well to augment the existing fresh water supply; and treatment of the waste water for the removal of the objectionable constituents.

The obvious procedure, however, involved the expense of drilling the new water well and the installation of a treating plant which would entail a continual operating expense for treatment of the waste water to render it unobjectionable. Faced with this problem,



Flow Diagram, Refinery Waste Water Recovery Plant

Feeding equipment for Lime and Alum used in treating refinery waste water.

the technical staff evolved the original idea of treating the waste water to make it suitable for reuse as condensing water—thus in one step eliminating the need for an additional water supply and obviating the contamination of a public supply by the refinery wastes. Being an original conception, no literature was available to serve as a guide in the installation of the contemplated waste water treating plant and it was therefore necessary for the technical staff to make a study of the chemical characteristics of the various wastes in order to determine the possible application of existing water purification methods.

The accompanying Plate No. 1 is a flow diagram of the water system of the refinery in question and this flow diagram is probably more or less typical of the average refinery. The chief waste products were the following:

WASTES HANDLED

From the zeolite softener, sodium, calcium and magnesium chloride during the regeneration period. From the gasoline treaters, calcium hydroxide and chloride, and free chlorine; from the kerosene treaters, sulphuric acid, pond water, caustic soda, lead and sulphur. From the doctor treatment, lead caustic soda and sulphur. From the gasoline towers, sulphuric acid and acid sludge. From the centrifuges, entrained oil. From the boiler blowdown, sodium hydroxide, carbonate, chloride and sulphate. And from the numerous oil water traps throughout the refinery a considerable quantity of emulsified oil finds its way into the waste water.

Of course, when the various wastes are combined in one receiving sump, the alkaline constituents of certain of the wastes react with the acid constituents of other wastes, resulting in a water having a dissolved mineral content substantially as shown in Table 1. Organic compounds, which are serious as a source of stream pollution, do not materially affect the use of water for condensing purposes and were therefore not investigated. The essential consideration in so far as the use of the water for condensing purposes is concerned is that it should be practically free from oil, safely alkaline and relatively low in temporary hardness.

To be definitely non-corrosive, it is essential that the water have a pH value well above 7; and for the removal of emulsified oil coagulation is necessary. Referring to Table 1, it will be noted that the pH of the composite waste water is 5.7 and it is therefore apparent that the alkalinity of this water must be increased in order to raise the pH to the desired value. Furthermore, since practically all of the commonly used coagulants are acid in their reaction, any attempt to coagulate the water without first raising the pH value and alkalinity would have resulted in a further decrease in the pH value.

Preliminary investigations on the treatment of the composite waste with lime to raise the alkalinity and the

TABLE 1

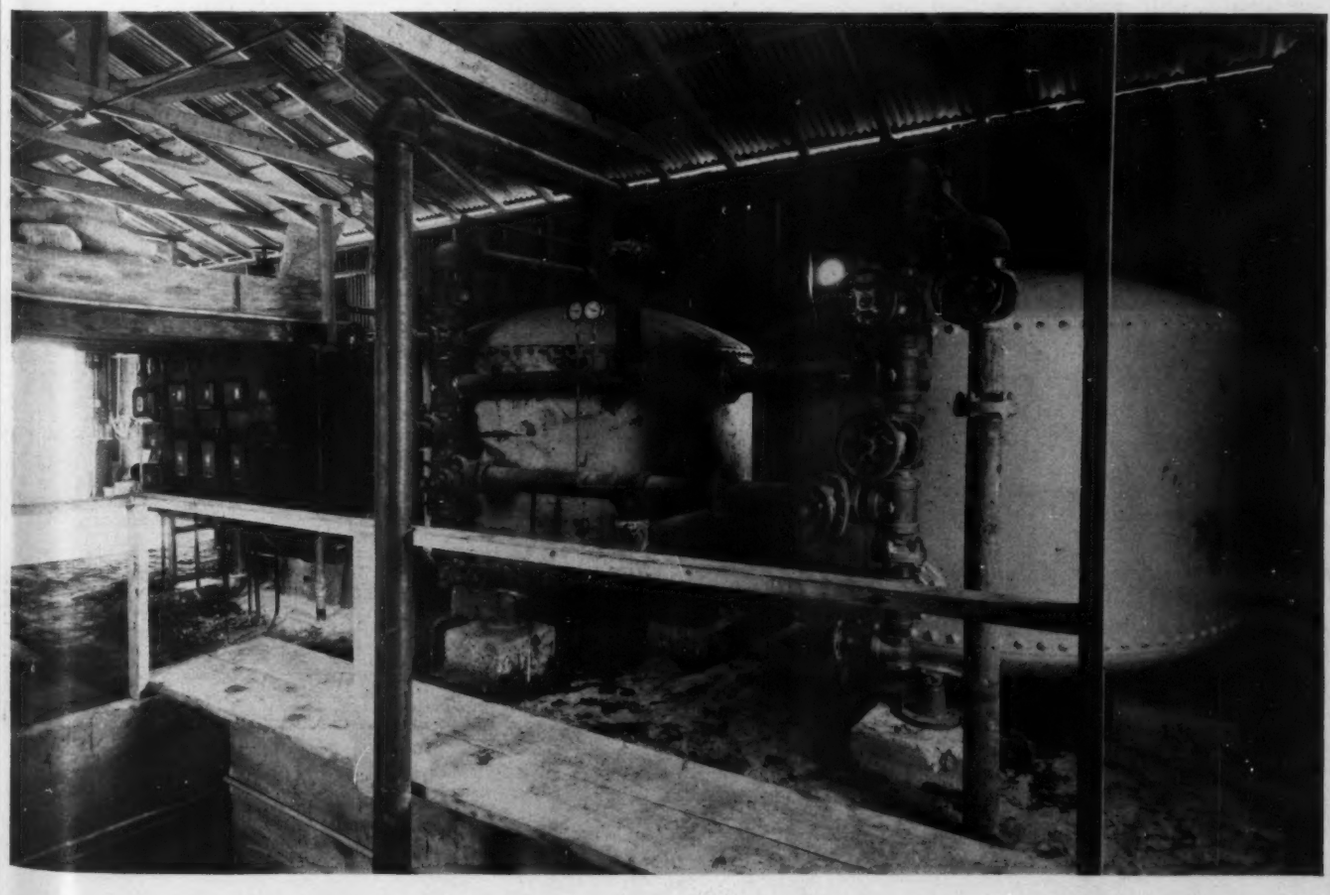
Color	Brown
Odor	Gasoline
Hardness	607 p.p.m.
Alkalinity	18 p.p.m.
Calcium Carbonate	18 p.p.m.
Calcium Sulphate	525 p.p.m.
Calcium Chloride	0 p.p.m.
Magnesium Carbonate	0 p.p.m.
Magnesium Sulphate	242 p.p.m.
Magnesium Chloride	0 p.p.m.
Iron Oxide	12 p.p.m.
Silica	22 p.p.m.
Total Dissolved Solids	2905 p.p.m.
Suspended Matter	720 p.p.m.
Sodium Sulphate	364 p.p.m.
Sodium Chloride	1689 p.p.m
Sodium Carbonate	0
pH	5.7

pH followed by the application of alum as a coagulant showed that a heavy and voluminous precipitate could be readily formed; and that this heavy and flocculent precipitate adsorbed and absorbed the turbidity, suspended matter, emulsified oil, etc., present in the water, causing it to settle out as a sludge. The water produced while clear, safely alkaline, and low in temporary hardness retained a strong oily odor which could not be removed by aereation and had a color of 30 to 40 on the color scale.

DETERMINING CAPACITY

The preliminary work described above having demonstrated the feasibility of treating the composite waste water to render it suitable for reuse for condensing purposes, the next step was to determine the capacity of the required treating plant for carrying out the procedure developed in the laboratory experiments. Weir measurements of the refinery waste water discharge ditch showed that the average flow was 120 gallons per minute or about 175,000 gallons per day. In so far as the handling of the waste water alone was concerned, a treating plant of this capacity would have met the requirements. However, the cooling pond water at the plant was in very bad condition and consequently it was decided to install a plant of double the capacity required to handle the waste water only in order that the cooling pond water might be continuously withdrawn from the pond and returned to it, thus eventually cleaning up and improving the condition of the pond water. The increased plant capacity also made it possible to handle any rain water run off from the refinery yard—the objective of the management being that no water would leave the refinery premises except by evaporation or seepage. With these various factors in mind, a treating

Installation of pressure filters used in conjunction with the waste water recovery system.



plant having a capacity of 250 gallons per minute was finally decided upon.

Equipment for the treating plant was furnished by International Filter Company and, in a general way, follows the lines of a conventional International water treatment plant. It consists of a lime and alum feeding equipment, a sedimentation tank provided with reaction chamber and sludge removal system and filters for filtering the chemically treated and settled water. The installation of the plant was made substantially along the lines as shown diagrammatically by Figure 2.

Composite waste water from the refinery enters the receiving sump which serves the dual purpose of equalizing the flow and of skimming the oil from the waste water. This oil is periodically pumped away from the sump and burned. From this receiving sump, the water is delivered by a booster pump through a rate of flow controller to the treating tank—the rate of flow controller serving to limit the discharge of the pump to a fixed quantity regardless of variations in suction or discharge head. The booster pump is started and stopped automatically by a float switch installed in the receiving sump, the booster pump operating in accordance with the volume of waste water delivered to the sump. This float switch also controls the operation of the chemical feeding equipment so that whenever water is delivered to the treating plant, lime and alum, the chemicals used in the treatment, are likewise delivered to the treating tank in order that the waste water may be properly treated.

SEDIMENTATION BASIN

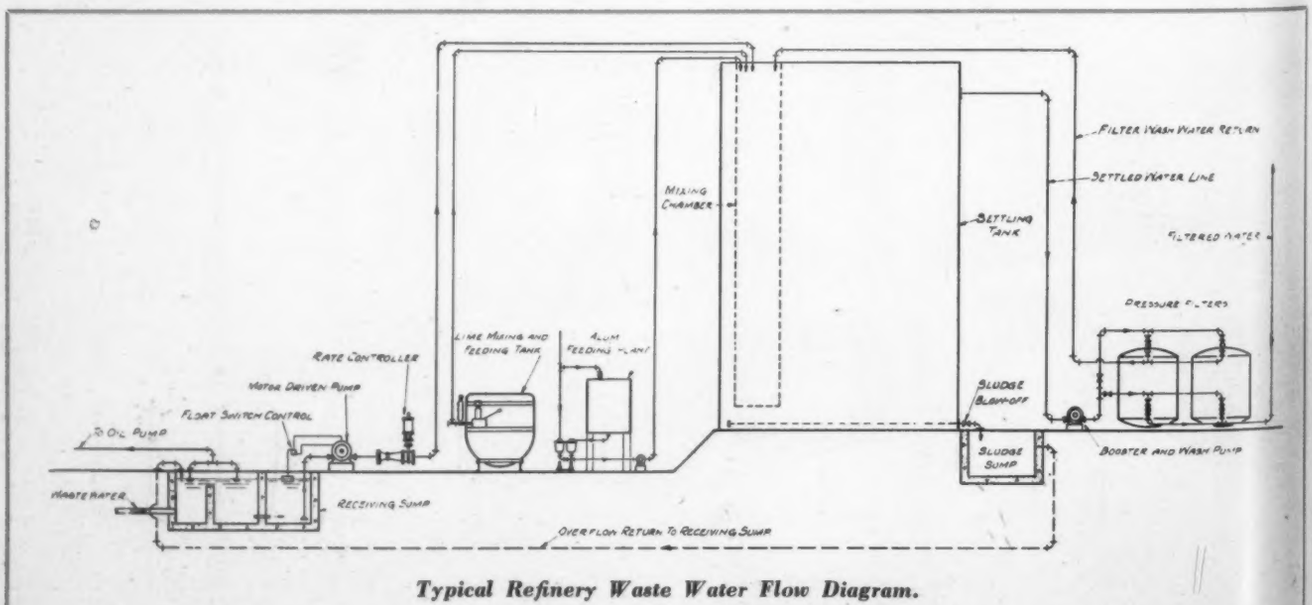
A standard 5000-barrel steel oil storage tank was utilized as the sedimentation basin for the treating plant, this tank being equipped with a downtake or reaction chamber five feet in diameter located at one side of the tank; and a sludge removal system consisting of a pipe spider extending over the entire bottom of the tank and terminating in quick-opening valves located outside the tank. It will be noted that the standard steel tank used, having a capacity of approximately 20,000 gallons, provides for a retention period of approximately 12 hours when the treating plant is operated at its rated capacity of 250 gallons per minute or 15,000 gallons per hour.

The discharge from the booster pump after passing through the rate of flow controller is delivered to the downtake or reaction chamber of the sedimentation tank in such a manner as to impart a rotary motion to the water. The treating chemicals—lime and alum—are delivered in such a manner as to strike the entering stream of water and this, together with the rotary motion imparted to the water in the downtake, assure thorough mixing of the chemicals with the waste water. The mixture of water and chemicals passes slowly downward through the downtake to the bottom of the sedimentation tank and during this period the chemical reactions take place, resulting in the formation of a heavy, flocculent precipitate.

Leaving the bottom of the downtake, the mixture of water and sludge passes into the main portion of the tank and during the slow upward travel to the outlet—near the top of the tank—the bulk of the sludge formed as the result of the treatment settles to the bottom and is removed from the tank by the sludge removal system previously described.

Chemical feeders are of the wet type. Because of the nature of the hydrated lime a specially designed feeder must be provided to maintain and deliver a uniform suspension of the mixture. The chemical feeder used provides for vertical agitation of the mixture, which has been found most effective in maintaining a uniform mixture of the lime in the water in which it is suspended. This feeder also provides for the delivery of the lime from this tank by pickup cups attached to, and revolving with, the agitators. Soda ash, if required, is fed from the same tank.

The alum or other coagulant is made up in solution



Typical Refinery Waste Water Flow Diagram.

form and is measured by means of an adjustable orifice box.

Discharges from the lime feeder and from the alum feeder are picked up by their respective pumps and delivered to the sedimentation tank.

FILTERS

Settled water leaving the sedimentation tank is passed through two pressure filters utilizing a specially graded sand as a filtering medium. The filters are backwashed with treated and settled water from the sedimentation tank; and this wash water is returned to the sedimentation tank for recovery. The filtered water is then delivered to the condensers in the refinery yard for cooling purposes, the delivery of treated water being automatically controlled by a float switch in the sedimentation tank which starts and stops the treated water delivery pump in accordance with variations in level in the sedimentation tank.

Heavy sludge deposited in the sedimentation tank as the result of the treatment of the water is removed by means of the sludge removal system and discharged into a fairly large basin from which the settled sludge is periodically removed in dry form by trucks, the overflow from this basin being returned to the receiving sump.

Referring again to Plate 1 showing the water system of the refinery, including the waste water treating plant, it will be observed that the system is a completely closed one, the only loss of water from the system being that due to seepage from the sludge receiving basin.

Operation of the plant is comparatively simple inasmuch as under normal operating conditions the composition of the waste water handled is not subject to extreme variations. The operation of the plant requires only periodic testing of the effluent from the plant in order that the proper chemical dosage of the waste water may be determined. On the basis of these tests, the chemical feeding tanks are recharged with the proper amounts of lime and alum; the sludge is blown down from the sedimentation tank and the filters are washed.

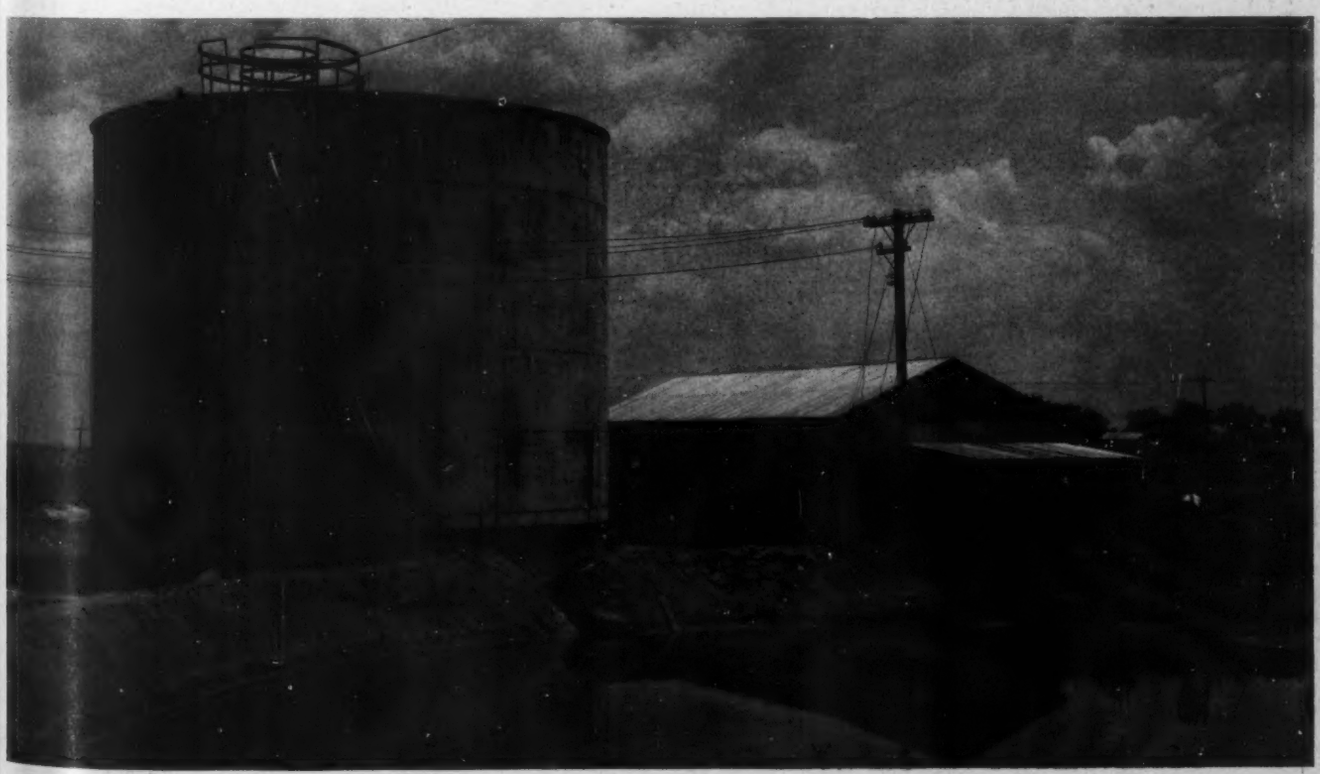
The treating plant as described above was placed in operation within two months from the beginning of the survey and with the exception of a few minor difficulties encountered, has been in successful operation from the start. Within a short time after the treating plant was placed in operation, the sewer outlet from the refinery yard was sealed; and since that time no water has left the refinery except by seepage.

Early in the operation of the plant it was found to be uneconomical to neutralize the acid sludge from the kerosene and gasoline agitators and it was therefore decided to use this acid sludge as a fuel for heating one of the oil stills, thus effecting a saving in both lime and fuel.

The volume of water recovered is greater than can be satisfactorily used for condensing and consequently a number of changes are being made to decrease the amount of waste water and to render the recovery plant effluent suitable for other purposes, particularly for steam generation.

The installation and operation of this waste water recovery plant demonstrates that refinery waste water can be satisfactorily conditioned for reuse for condensing purposes with consequent reduction in the amount of fresh water required for refinery purposes and with the reuse of the waste water stream pollution is avoided.

Sedimentation tank, chemical house and sludge basin in waste water recovery system.



THE PROBLEMS OF . . .

Technical Progress

GEORGE REID
Associate Editor

"WE believe that hydrogenation is coming rapidly. We are going to wait for developments and see how the trend goes before doing further important work at our refineries." This was told the sales manager for a manufacturer of auxiliary equipment by an executive of a refining company. The manager of sales was mulling over this answer when the writer called, and the problem proved worrisome. "What is the answer? Will they all feel that way? Why don't you write an article . . . ?"

Obviously the suggested article can not deal with hydrogenation alone. That process is but one (although the most important, technically) of the developments in refining technique that contributes to delaying decisions at meetings of executives and directors studying the problem of refinery modernization or expansion. Mention of that process here only exemplifies the influence of technical progress in the industry. Soon or later many or all of the 15 companies interested in Hydro Patents Company (and other concerns not now financially involved) will become interested in hydrogenation to the point of construction of the system. How soon, or how much later, depends upon a number of factors now difficult of analysis and appraisal.

Ultimately hydrogenation will influence all refining processes and departments—distillation, cracking, lubricating oil manufacture, wax, fuel oil and chemical treating. At present there are processes recently perfected, and processes now being developed in each of the major departments of the process work that are distinct improvements, and their adaptation involves changes in design of equipment, changes in operating technique and control, changes in demands for materials and supplies by the industry, and changes in viewpoint of the operating personnel. Progress, technical advancement, lets nothing stand still—either materials or men.

Perhaps the refining company executive was (as executives often do) only temporizing, or perhaps his company prefers to await developments and he was serious in his contention. But let us assume that his company operates three, four or five refineries in various parts of the country. It can be further safely assumed that those refineries are between 25 and 40 per cent obsolete in their distillation and cracking departments, and further, that insofar as cracking units are concerned the plants are out of balance and sufficient quantities of cracked gasoline can not be produced. Save where refineries have been modernized but recently, and their cracking departments expanded, such conditions prevail throughout the industry. Further, cracking equipment five years of age is obsolete, usually. One estimate states that the industry is spending around $100,000,000 annually combatting corrosion, obsolescence and "wear and tear." Other estimates are higher. Any company, however, with a group of refineries can spend a couple of millions on its properties, virtually any time, and usually profit by it.

Members of research departments, engineers, technologists, consulting engineers, organizations of construction and development, and general equipment manufacturing concerns, must be constantly alert to the rapid progress of technical development. The industrial picture once did, can again, change swiftly.

Listen in at a conference of engineers, technologists, superintendents and executive supervisory personnel when the refining company with the assumed three, four or five plants takes up the problems of modernization. Perhaps a consulting engineer sits in. Most of the companies desire him, to secure the outside viewpoint.

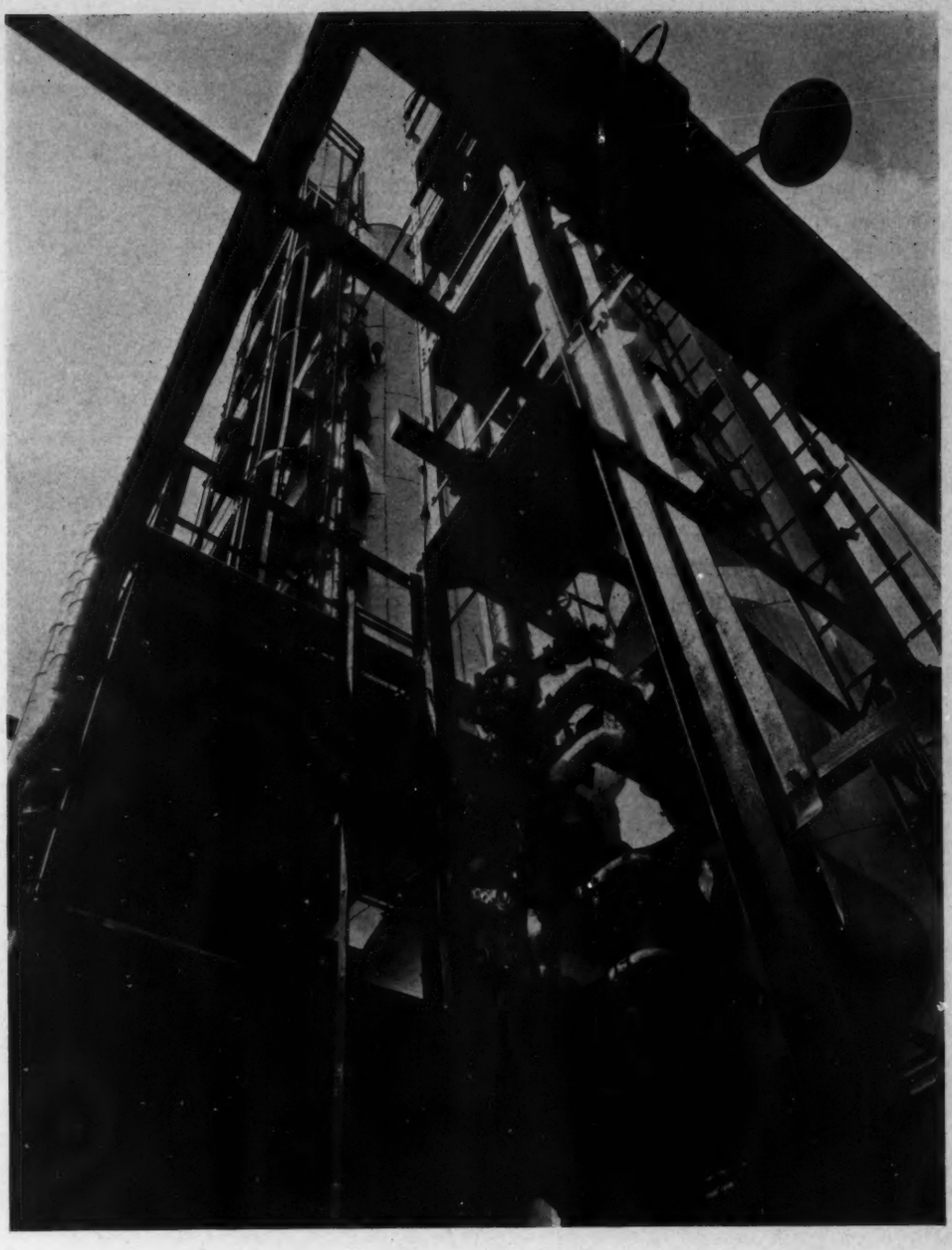
The bone of contention finally shows up in the form of the refinery that has been long neglected—for some reason one of them usually is. Perhaps it was once to be abandoned. However, local changes have brought it distribution of products and field developments have brought it nearby crude supplies. Its batteries of shell stills, equipped with bubble towers six year ago, have served their term of usefulness. Its cracking equipment is of 1924-25 vintage. It produces lubricating oil and greases, and its treating costs are high and the octane rating of its gasoline production needs boosting. Competitive conditions are threatening the slight margin of profit. It is to be rebuilt.

In this preliminary conference distillation and cracking departments receive first attention. A number of arrangements present themselves. Atmospheric distillation in modern tube stills, vacuum distillation only, or combination atmospheric-vacuum type of operation can be installed. Another scheme is combination skimming and cracking, which can include reforming of the naphtha fraction—charging crude direct to the unit. Perhaps

the other method of atmospheric distillation of crude, vacuum rerun equipment, is desired. Will this require cracking stills for topped crude, cracking equipment for gas oil and other cracking equipment to reform naphtha?

Perhaps the characteristics of the crude point to gas oil cracking, and coking operations are to receive study. Will the old shell still coking operation suffice, with high operating costs, its biannual replacement of coking still bottoms, or will the newer coke ovens with special alumina clay tile hearths be installed to produce the increased yield of gas oil?

These matters will bring up the question of liquid or vapor phase cracking, or combinations of liquid-vapor phase work. Will it be advisable to produce asphalt from the cracking still residue, air or steam blown? Road oils? Shall reforming of naphtha, if reforming is individually done, be low or usual pressure, or extreme high pressure work? If vapor phase cracking produces additional gas yield, shall new processes for the polymerization of these gases under heat and pressure conditions be investigated and installed? Perhaps it will be necessary to look into the processes for manufacture of synthetic alcohols and solvents from the cracking still gases. Here is a field that has been scarcely scratched.



The new gasoline recovery and stabilization plant at Continental Oil Company's Ponca City refinery as seen by the modernistic photographer. This picture was secured by pointing the camera skyward from the base of the unit.

Many factors influence the designation of type of distillation and cracking facilities, each of which must be studied, and the best arrangement of facilities be determined upon which will best serve the major interests or factors. And, perhaps in arranging the refinery it may be well to install supplementary equipment for the pre-stabilization of the fresh crude, removing the lighter portion before sending the oil to storage.

In the production of fuel oil through operating cracking units on topped crude, can the unit desired be so handled that Bunker C specifications can be met or shall a process for the clarification of cracking unit residues be installed using acid, flocculators and filters? Perhaps the new colloidal fuels now being investigated commercially indicate a small but growing market for a different type of fuel. And in regard to fuel gas derived from cracking still operation through the vapor recovery system, shall it be consumed or marketed to the nearby metropolitan utility company?

Provided with cracking facilities the refinery must have a gasoline recovery and stabilization system. The absorption or compression recovery system, or the combination system are available. Where distillation is required, would they follow the modern trend of two-stage distillation, securing lower operating costs? The

choice of systems is determined by factors existing on the individual refinery yard, and engineering opinion. The sour gas can be washed free of hydrogen sulphide at reasonable cost if desired. The stabilization facilities may stabilize pressure distillate, or may be used only on gasoline produced direct from the cracking units and gasoline from the recovery plant. Perhaps the light fractions secured by pre-stabilization of the incoming crude oil would be included. The recovery and stabilization unit has become an importantly necessary adjunct to the refinery and must be included in modernization work. Whether or not the lighter hydrocarbons will be liquefied and isolated as special products, synthesized to special solvents, or alcohols, will constitute another avenue of investigation.

CHEMICAL REFINEMENT

Having gone over the ground, partially, in regard to distillation, cracking, recovery and stabilization, the conference will deal with chemical refinement. Among the older processes are sulphuric acid treating, caustic and sodium plumbite, sodium and calcium hypochlorite treating, with some work being done with ammonia as a neutralizing agent, and zinc chloride as a treating chemical; and with investigation pointing to some success with magnesium hydroxide, phosphorous pentoxide, and other reagents. Factors too numerous to mention here influence the decision. Distillation in the presence of treated clays is offered. Continuous centrifugal acid treating has gained impetus. Cold treating of cracked naphthas with acid is practiced. The use of polymerizers filled with fullers earth is growing and the process is offered for use with all types of cracking facilities. A continuous process uses earth or clays, heat and pressure, polymerizing undesirable constituents extracting them from cracked distillates. Finely divided copper is mentioned in a recent patent. A cold clay treating process is reported under development. The field is one wherein a great amount of research and investigation is under way which points to a possible revision of former practice.

In the lubricating oil field where sulphuric acid has held sway for treating, further work is being done. Sulfur dioxide extraction methods have proven beneficial and late development in this process includes the use of another slovent in combination with sulfur dioxide which has proven valuable with certain type of oils. One company successfully uses benzol in solvent extraction in treating lubricants. Many solvents are being employed, among them being propane, acetone, and others. Much of the work is directed toward simpler methods of wax removal, including the press and centrifuge, or both. New processes in this field are to be announced which will modify present practice both in wax removal and in chemical treatment. In the meantime new processes are available for the concentration of sulfuric acid and the manufacture of sulphuric acid on the refinery yard, and in this latter, using some of the refiner's favorite curse—hydrogen sulfide. These developments will contribute to lowered acid costs, and to less acid purchases by the industry, at the same time aiding in the solution of the acid sludge disposal problem.

In the manufacture of lubricants and greases, other developments are under way in addition to those mentioned above. The use of flue gases for blowing down or drying filters is being adopted in connection with the modern, continuous vacuum filter plants and the flexible pressure filter plants. These are improvements in wax sweating. Experience and research has given improved controlled operation of multiple hearth furnaces used in roasting fullers earth.

GREASE PLANTS

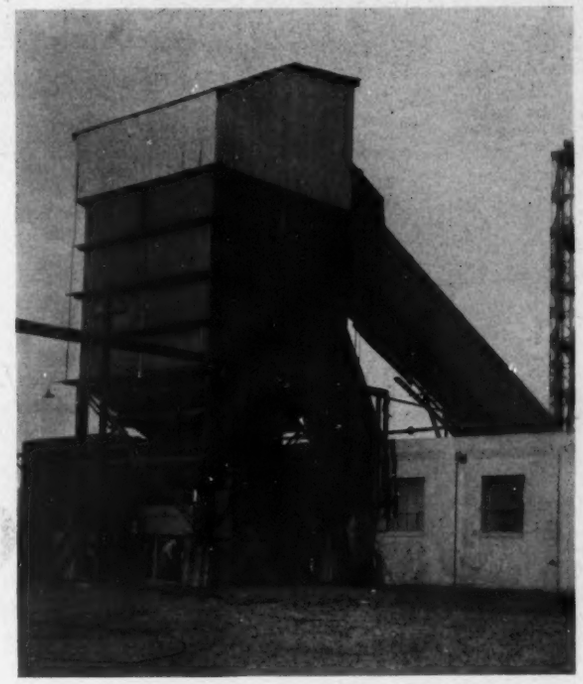
The grease plant department of the refinery has been adopting pressure saponification, adding the pressure kettles to the plant formerly using only open kettles, and speeding up the output of finished greases, cutting down the cost-per-pound. The process now demands the presence of grease filters for removal of rust, lime specks, etc. Lead soap greases were developed for extreme pressure lubricants. They preceeded a similar investigation in the lubrication field where metallic oxides are added to oils when claims of workers pointed to a deposit of the added metal on working parts of machines lubricated with it. In the grease field a new development points to the possible supplanting of compounded extreme pressure lubricants by a product derived from paraffin base petroleum by distillation. In this field much advance has been made. Essentially the processing steps are similar to those of years gone by excepting for pressure saponification, and different means of heating kettles. The principle factor in securing economy is that of design of the grease plant.

Having listened in at the conference through all the discussion of possibilities, processes, systems, developments, in each of the major departments of the complete refinery to be rebuilt, it is necessary to admit that the conferees did not thoroughly cover the ground and that they omitted discussion of a number of highly interesting developments in certain departments that would have given additional value to this report. Needless to state however (for such is always the case), part of their discussion was censored at the time or deleted from the written report.

One thing is clear, however, and that is that technical advancement is fast. The difficulties involved in proper selection of refining facilities are numerous. The problem becomes all the more intricate through knowledge of the fact that what is selected and constructed today, will in all possibility be obsolete five or six years hence, for this industry has definitely abandoned its old fashioned "hammer and tong" practices.

Facilities For Handling Petroleum Coke

AT Parco, Wyoming, Producers and Refiners Corporation operates an unusual and efficient coke handling system as an integral part of the refinery equipment. The original installation was installed in 1920, to function in connection with 10 Dubbs units. When the cracking department was rebuilt to include six larger Dubbs units, the coke handling system was redesigned to fit the new conditions.



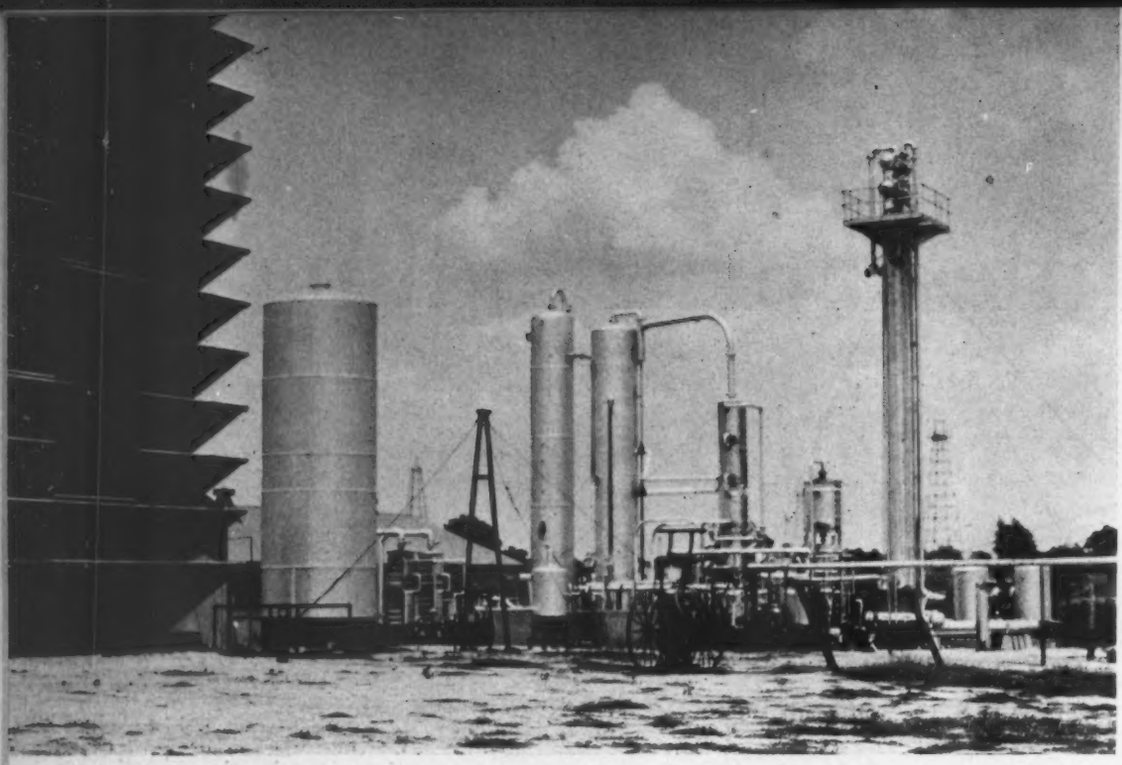
Hopper in Which Coke is Dumped from Conveyors

A tunnel was dug under the reaction chambers used in connection with the six cracking units. This tunnel was lined with concrete. Through the full length of this tunnel, a horizontal conveyor was placed, having a length of 190 feet, containing 390 chain plates. An inclined conveyor, connected to the horizontal one was constructed having a length of 105 feet with 234 plates. Each conveyor is dependent upon the other for operation, with the inclined conveyor acting as the driving medium. for the horizontal. The inclined conveyor runs at a slightly higher speed than the horizontal in order that the coke falling from the horizontal will be moved faster and not pile up.

Two openings are provided at each reaction chamber, one directly under the manhole and the other just outside the supports for the equipment. Heavy steel doors are used to close the openings and any tools and equipment utilized in operating the crackers may be moved over the roof of the tunnel and doors with safety. When operating the conveying equipment, the door under the chamber about to be pulled is opened. As the coke is removed from the interior, it falls through the opening onto the belt of the horizontal conveyor. Trouble was experienced at first through large pieces of hard coke falling directly onto the conveyor and damaging the belt. To remedy this, a heavy piece of boiler plate was welded to the frame of the opening, dropping downward at an angle. With these buffer aprons in place, large pieces of coke falling from the chamber when the cable is pulled or when picking the sides clear of coke, will strike this apron and it will bear the brunt of impact. At times when the coke comes out freely, it will load the conveyor and have a tendency to spill over the side. To correct this, a wiper plate was welded to the frame of the auxiliary doors and when an unusually large load falls to the conveyor, it is wiped back and distributed evenly on the conveying equipment.

At the upper end of the inclined conveyor, a hopper was built which has a capacity of 110 tons of coke. It is built with an inverted pyramidal bottom, perforated on all sides so that the water may drain from the stored coke before it is loaded on the miniature railway for movement to the coke storage pile. Each day as one of the reaction chambers is cleaned of coke, and about 65 tons are manufactured each 24 hours, the coke is moved from a hopper. A clamshell opening on the under side of the coke bin permits the operator to remove only as much as is needed to fill the coke cars in the train.

The unit is operated by one man who attends to the cable drum as well as the conveyor. When he is pulling the cable, the speed of the conveyor is regulated according to the free falling of the coke. An 11 x 12 Ajax drilling engine furnishes the power for operating the conveying equipment, the primary drive being through a belt from the pulley of the engine to a pulley on the upper chain drum of the inclined conveyor.



Harmony Gasoline Plant of Arkansas Fuel Company at Willow Springs, Texas.

DESIGN OF Gathering System

Important in Gasoline Plant Construction

THE elimination of losses due to friction in gasoline plant gathering lines has claimed the attention of engineers for many years. Most plants when built have only two main trunks reaching out in opposite directions; one of them from one end of the engine room or plant site and the other from the opposite end. These lines are laid as far as thought necessary, then lateral lines at right angles are placed to take care of the field in transporting the casinghead gas to the plant. Consequently, when engines are utilized, considerable vacuum is necessary to move the gas, and in most instances, a pressure exists on the wells farthest from the intake header. Generally, unsatisfactory performance is the result and more equipment is installed than would be required if field lines were designed and laid to permit an easy flow with a minimum amount of back pressure or drop in vacuum.

To eliminate both the frictional losses and unsatisfactory operating conditions resulting from lines consisting of only two main trunks placed in opposite directions, K. E. Jones, superintendent of Arkansas Fuel Company's natural gasoline division together with E. P. Farmer, superintendent of the company's Harmony Gasoline plant near Willow Springs, Lathrop area, East Texas, designed the field layout before any excavation work had been started, but after the field tests had been completed showing from which wells the principal gas volume was to be secured.

The plant site was selected in relation to the approximate center of the area from which the gas was to be gathered, but with the major portion coming from the southwest, and the next larger volume available from the wells northeast of the site.

Terminal drums were installed and placed underground at both the east and west end of the engine room, made from tanks three feet by twelve feet in dimensions. These receivers are utilized as mist extractors or header drips in addition to equipment to which the trunk gathering lines were to be connected. From the engine room side of these drums, the line leading to the compressors was welded at an angle of 45 degrees to the horizontal of the gathering trunk lines, connecting the drums with scrubbers. The scrubbers were set in line with the com-

pressors, and the header to which the compressors are connected was welded to the scrubbers at an angle of 90 degrees to the vertical.

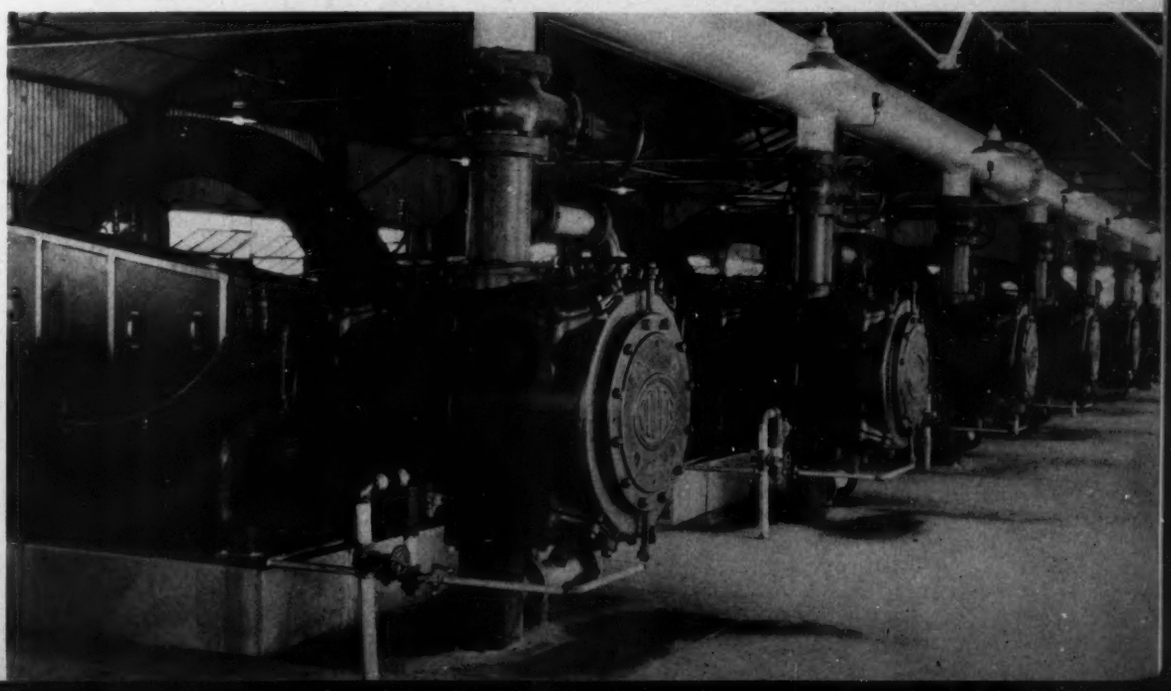
This header extends through the engine room, connecting the scrubbers at each end of the plant. Instead of being suspended above the roof trusses of the building, or buried, or set in conduit, the intake header passes through the building as near the intake flanges of the cylinders as it could be with connections made between it and the engines. A short nipple was welded to the underside of the header with a gate applied and next a short nipple between it and the flange of the cylinder, each one being as short as practicable with the lower one installed with the by-pass connection leading to the discharge welded between the control gate and the compressor flange. The discharge header was laid outside the engine room and underground. Each individual line from the compressors lead directly to it with the control gates just inside the engine room wall.

GATHERING SYSTEM

In designing the field gathering system, three main trunk lines extend in as many directions from each terminal drum at both ends of the engine room, six in all, radiating from the plant in a circular fan shaped plan. Weymouth's formula was employed throughout when laying the lines, and provisions were made in selecting the proper size that a minimum amount of back pressure would be encountered when the plant was placed in operation. For instance the line leading from the southern end of the west terminal drum and extending to that area south of the railroad west of Willow Springs. It was begun at the plant with 14-inch pipe, telescoping down as it was laid from the plant to 12-inch, 10-inch and four-inch at the well end. Each lateral from the main trunk to the separator at the well is laid of four-inch pipe, and connected to the main line at an angle which permits the gas to enter without breaking over in a sharp turn. With the exception of the line extending to the northeast, all have eight-inch at the beginning, reducing to six- and four-inch at the well connections. The line to the northeast was begun with 12-inch, telescoping down through 10-, 8-, 6- and four-inch at the separators. The two lines leading to the northeast and to the northwest are looped together at the farthest end of the eight-inch sections. The loop will be continued until a circular system of pipe lines connect the main trunks out in the field. In an old settled field with a slow decline in gas volume, or one in which the initial volume per well is low, this procedure would not seem so essential, but under the operating conditions as encountered in East Texas, it seems to be a logical method of gathering the gas with the least difficulty.

The initial installation of engines in the plant consists of eight type 80 Cooper Bessemer gas engine driven compressors with 17-inch by 20-inch cylinders. Provisions are made by which the extension may be made from either end or both of the engine room to take care of an increased volume of gas when additional wells are drilled or operating conditions change the allowable of those wells now being produced.

The process side of the plant is little different from others being operated over the country. Southwestern absorption and distillation equipment with a Braun fractionator are being operated. Ten inches of vacuum is being pulled on the field terminal drums, and through the circular fan shaped gathering system, a vacuum of not less than two inches is available at the regulators placed on the separators of the most distant wells, and this in spite of the fact that there are approximately 30 miles of pipe in the gathering system.



Harmony Gasoline Plant of Arkansas Fuel Company at Willow Springs, Texas. Showing method of short connections between intake header and compressors.

Survey of Cracking Plants Shows Continued Expansion

G. R. HOPKINS
*Economic Analyst, U. S. Bureau of Mines**

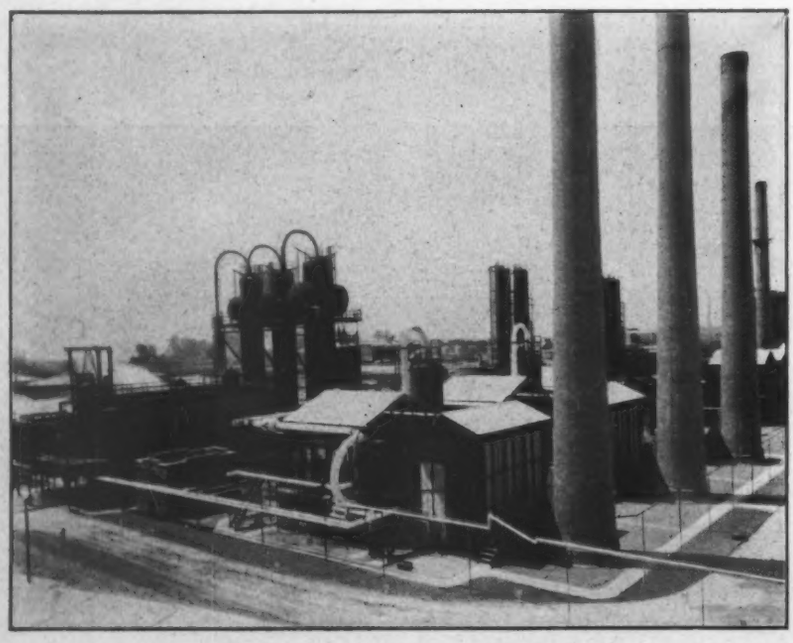
TOTAL daily charging capacity of the cracking plants in the United States as of January 1, 1932, amounted to the record total of 2,046,981 barrels. This represents an increase over the previous year of 96,200 barrels, or five per cent. Although the increase in total charging capacity of the cracking plants during 1931 was considerably less than in 1930, it was about three times the increase in the capacity for straight distillation.

Total daily charging capacity of the plants operating on January 1, 1932, amounted to 1,603,809 barrels, or 78 per cent of the total; the capacity of the inoperative plants was 394,585 barrels, or 19 per cent; that of the plants under construction was 48,587 barrels, or three per cent. Compared with a year ago, these data represent a small increase in operative capacity, a large gain in inoperative capacity, and a large decrease in the capacity under construction. The refinery survey showed a comparable increase in the inoperative capacity of the equipment used for straight distillation, but showed a decrease in operative capacity and a much larger relative decline in the capacity under construction. These facts indicate an expansion in cracking at the expense of skimming.

In cracking, as in practically all industrial operations, capacity may be increased either by constructing new units or by remodeling existing equipment. Until five years ago most of the capacity that was added consisted of new equipment, but the last few years have witnessed a tendency to increase the potential throughput by modernizing existing units. It is estimated that at least 125,000 barrels of daily cracking capacity was added through remodeling in 1931, compared with about 150,000 barrels added through the construction of new equipment. On the other hand, the cracking capacity is also reduced in two ways, by the dismantling of old units and through obsolescence. It is estimated that about 110,000 barrels of capacity was dismantled in 1931 and that about 70,000 barrels was lost through obsolescence.

The number of cracking units as of January 1, 1932, totaled 1348, compared with 1868 a year ago. This material decline resulted chiefly from the dismantling of a large number of Burton stills of small capacity. The number of units has shown a steady decrease in recent years, the total capacity a steady increase. This trend is indicative of the tendency of refiners to replace small, obsolete units by one or two large modern units. For example, the average size of the cracking units on June 1, 1925, the date of the first cracking survey, was 330 barrels; on January 1, 1932, it was approximately 1500 barrels.

*Reprinted from U. S. Bureau of Mines Information Circular 6648.



TEXAS LEADS

Texas continued to rank far ahead of the other states in total capacity of cracking plants; California was second, Indiana third. The total capacity of the cracking plants in Texas, which are largely concentrated on the Gulf Coast, amounted to 645,720 barrels, or 32 per cent

of the total for the United States. In a number of states the capacity of the plants dismantled in 1931 exceeded the increase due to new construction or to the remodeling of old units. Wyoming showed the largest decrease in capacity during 1931; Oklahoma showed a decline for the second consecutive year.

Thirty-seven different types of cracking processes were reported in this survey compared with 35 a year ago and with 27 in 1925. Approximately half of the number of types listed in 1925 were reported in the 1932 survey, from which it may be assumed that about two dozen new types have been developed in the intervening seven years. The number of processes showed the most rapid increase in 1928; since then the number of new processes developed has about equaled the number no longer reported.

The various types of cracking processes may be divided into two general classes, one comprising those which have been actively licensed, the other made up of those that have been used exclusively by the respective companies which designed them. For purposes of designation, these groups will be referred to as the "license" and "own" groups. At the time of the bureau's first survey (1925) the license group was of primary importance, but the last few years have witnessed a rapid increase in the capacity of the "own" group. For example, between January 1, 1931, and January 1, 1932, the total capacity of the "own" group rose from about 930,000 barrels to 1,060,000 barrels; the total capacity of the "license" group declined from about 1,020,000 barrels to 990,000 barrels in the same period.

VAPOR PHASE SHOWS GAIN

Cracking processes may be further divided into those which operate in the liquid phase and those which operate in the vapor phase. Liquid-phase processes were the first to be developed. The development of vapor-phase units was given an impetus by the discovery that the gasoline produced by them had an unusually high anti-knock rating. Thus the total capacity of the vapor-phase units practically doubled between January 1, 1930, and January 1, 1932. However, it should be noted that the total daily capacity as of January 1, 1932 (60,350 barrels), represented only about 3 per cent of the total.

Production of gasoline by cracking has shown a steady increase in recent years; in 1931, the output of cracked gasoline totaled 176,181,000 barrels, an increase of seven per cent over 1930. As the output of all grades of gasoline at refineries showed a small increase in 1931, it follows that the proportion of cracked gasoline to the total increased materially. It might be assumed that, in times of low crude prices such as prevailed in 1931, the skimming of crude oil would be preferable to cracking. Actually the reverse held true; that is, cracking increased materially and skimming declined. At some refineries all the skimming units were shut down for months at a time and only the cracking plants operated. In some cases this was due to a restriction in the supply of crude oil, but in general it was a tribute to the increased efficiency of cracking plants.

Data as to the gasoline yields obtained by cracking vary widely, depending upon the type of process, the charging stock, and the extent of recycling. In 1925 the average gasoline yield reported by all the companies was 33 per cent of the charging stock. In 1931 an analysis of the reports of about 25 large companies showed a yield of 45 per cent, indicating a material improvement in efficiency.

TABLE 1

Types of Cracking Process, Number in Use and Capacity, as of January 1, 1932, compared with January 1, 1931*

Type of Process	January 1, 1932		January 1, 1931	
	Total Units	Total Capacity, Barrels per Day	Total Units	Total Capacity, Barrels per Day
Black	12	16,000	12	16,000
Burton	320	83,774	793	164,249
Carborundum	1	3,000	1	3,000
Coil cracker	.....	.....	2	8,000
Combination	1	12,000	.....	.....
Continuous high-pressure	3	10,947	2	5,300
Controlled coil	8	24,500	2	4,500
Convertor	1	4,800	1	4,200
Cross	151	241,370	150	245,800
de Florez	12	24,700	6	13,550
Doherty	21	29,000	20	27,500
Donnelly	3	5,500	4	7,000
Dubbs	173	261,950	185	252,250
Fleming	3	600	2	800
Gyro	21	20,400	20	16,000
Holmes-Manley	113	262,200	115	233,900
Isom	95	123,500	115	179,150
Jenkins	44	65,300	46	66,150
Leamon	5	2,500	5	2,250
Lewis	4	6,200	4	6,200
Lientz	1	6,000	1	6,000
Link	22	46,000	22	46,000
Louisiana coil	.....	.....	5	7,100
Ormont	4	1,000	4	1,000
Own	119	168,500	166	168,000
Pipe Stills	3	13,000	3	13,000
Pratt	2	2,500	2	2,500
Pressure-coke	11	19,000	13	22,000
Richmond	1	3,000	2	6,400
Rowsey	1	10,000	.....	.....
Sinclair Type 600	25	87,000	.....	.....
Skelly-Rittman vapor-phase	2	2,500	2	2,500
Slagter	15	2,250	18	2,700
Snodgrass	7	2,700	14	4,972
Solar	1	7,150	.....	.....
True vapor-phase	2	4,600	2	3,600
Trumble	1	750	1	750
Tube-and-tank	127	441,540	118	385,460
Vapor-phase	2	2,150	3	4,200
Winkler-Koch	11	29,100	7	18,800
TOTAL	1,348	2,046,981	1,868	1,950,781

*From U.S. Bureau of Mines Information Circular 6648.

Correlation of Knock Ratings

Road-Test Method Developed and C. F. R. Laboratory Procedure Modified

(Reprinted from S. A. E. Journal)

SATISFACTORY correlation between the knock intensities of fuels rated in cars on the road and the octane-number ratings of fuels as determined on the C.F.R. engine is the outcome of an intensive period of cooperative road and laboratory test work conducted under the direction of the road-test correlating group of the C.F.R. Detonation Subcommittee. This correlation has been made possible by the development of a method for making road knock ratings and by minor modifications in the C.F.R. apparatus and procedure, both of which received the approval of the Cooperative Fuel-Research Steering Committee at its recent meeting. The modified knock-testing procedure was officially designated as the C.F.R. Motor Method, with an order to retain the old method for experimental purposes under the title C.F.R. Research Method.

NEED FOR CORRELATION RECOGNIZED

For some time the members of the Detonation Subcommittee, of which T. A. Boyd of the General Motors Corporation Research Laboratories is chairman, had been aware of the need for investigating the problem of bringing laboratory knock ratings of fuels in closer agreement with the actual performance of fuels in cars on the road.

Early in 1932, a committee headed by A. L. Beall of the Vacuum Oil Company, as chairman, was appointed as a sub-group of the Detonation Subcommittee to investigate this problem and to develop a road-test procedure. That subcommittee rendered a report at the time of the summer meeting of the Society of Automotive Engineers with recommendations which included the suggestion that a larger, more representative subcommittee be formed to determine the average deviation of road-test results by the proposed method from results obtained by the standard procedure on the C.F.R. engine.

ROAD TESTS CONDUCTED ON UNIONTOWN HILL

Accordingly, a volunteer committee was formed which included in its membership representatives of 14 automotive and petroleum laboratories and continued under the chairmanship of Mr. Beall. The program of work laid out by that group, known as the Road-Test Correlating Sub-Subcommittee, provided that each cooperating company should send accredited representatives and trained operators to meet at Uniontown hill, Uniontown, Pa., on August 3, so that a series of cooperative road test on representative fuels and cars might be conducted to determine the significant road knock rating of a motor gasoline.

The official operating representatives of the laboratories engaged in this work were as follows:

H. W. Best, Yale University; F. C. Burk, Vacuum Oil Company; J. M. Campbell, General Motors Corporation; A. L. Clayden, Sun Oil Company; E. Dunning, Shell Petroleum Corporation; W. M. Holaday, Standard Oil Company, (Indiana); G. A. Hope, Standard Oil Company of New York; C. A. Kass, Standard Oil Development Company; A. W. Pope, Waukesha Motor Company; J. R. Sabina, Atlantic Refining Company; C. B. Veal,* Society of Automotive Engineers, Inc.; L. B. Voshall, The Texas Company; Cleveland Walcutt, Ethyl Gasoline Corporation; Gilbert Way, Chrysler Corporation; N. R. White, Bureau of Standards.

Others present who assisted materially in the formulation and conduct of the tests were:

A. L. Beall, Chairman Vacuum Oil Company; H. F. Huf, Vice-Chairman Atlantic Refining Company; W. Anderson, Chrysler Corporation; J. G. Cook, The Texas Company; B. W. Dickinson, Bureau of Standards; H. L. Horning, Waukesha Motor Company; S. P. Marley, Vacuum Oil Company; L. E. Rinker, Shell Petroleum Corporation.

THE CARS AND FUELS TESTED

Fifteen cars, including the popular makes and models now on the road, were tested. These were the Buick 32-67; Ford Model A; Ford V-8; Chrysler 8, 1932; Hudson 1932; Nash 1932; Oldsmobile 1932; Plymouth 1932; Studebaker President 1932; Dodge 6, 1932; Chevrolet 1932; Chevrolet 1932, high compression; Buick 1931; Chrysler 1931, high compression, and Studebaker 1930, high compression.

Fifteen fuels selected as representative of the entire range of commercial gasolines were used in the tests. The fuel samples were labeled with a system of letters and numbers, the key to which was known

*Secretary, Cooperative Fuel-Research Steering Committee.

only to the Secretary of the Committee and which has since been destroyed to avoid any possible identification of commercial gasolines. The fuels included were a liquid-phase cracked gasoline, a vapor-phase cracked gasoline, a blend of 65 per cent of the above liquid-phase cracked gasoline and 35 per cent of the Reference Fuel A, a blend of 50 per cent of the above vapor-phase cracked gasoline and 50 per cent of the Reference Fuel A, and a group of commercial fuels known as the UT Series, which included Gulf, Tydol, Sunoco, Texaco, Atlantic White Flash, U. S. Motor, Amoco, Atlantic-Ethyl, Penreco-Ethyl, a cracked California and a straight-run California gasoline.

The road tests continued from August 3 through August 17. All results obtained represent the findings of at least two groups of men, sometimes of three or four groups, usually three men to a group. More than 2500 runs were made up the hill, and approximately 10,000 observations of knock were recorded. No individual laboratory has available enough trained experts to approach this quantity of work, even over a long period of time. Cooperative effort alone is responsible for the mass of data collected.

These data were carefully analyzed, tabulated and plotted. The graphs indicated knock intensities, knock ratings over the entire knocking range and maximum knock ratings. These data, boiled down into one chart, showed the maximum spread in ratings obtained on each fuel for each car and the average of maximum knock ratings for each fuel in each car.

Table I
Summary of Ratings on Fuels Tested at Uniontown*

	C.F.R. Research Method		Road Ratings		C.F.R. Motor Method	
Fuel	Reference Fuel C in Reference Fuel A, Per Cent	Equivalent Octane Number	Reference Fuel C in Reference Fuel A, Per Cent	Equivalent Octane Number	Reference Fuel C in Reference Fuel A, Per Cent	Equivalent Octane Number
RT- 9	95	75	77	70	74	70
RT-10	111	79	75	70	74	70
RT-11	66	68	54	64	55	64
RT-12	68	68	49	63	50	63
UT- 1	82	72	63	66	62	66
UT- 2	1	50	4	50	4	50
UT- 3	56	65	53	64	54	64
UT- 4	61	66	55	64	55	64
UT- 5	75	70	63	66	64	66
UT- 6	110	79	100	77	103	77
UT- 7	69	68	56	65	58	65
UT- 8	82	72	70	69	70	69
UT- 9	76	70	67	68	68	68
UT-10	103	77	94	75	88	73
UT-11	111	79	102	77	90	74

*The values are based on very limited calibration made at Waukesha and, while accurate within commercial limits, are subject to further check.

MAXIMUM KNOCK RATINGS SIGNIFICANT

A study of these charts revealed three important findings:

(1) The spread of knock ratings, with the exception of three cars, was about 20 per cent of Reference Fuel C, or about 5 octane numbers for commercial fuels. For the straight cracked fuels, the spread was much greater. It should be understood, however, that the spread as plotted did not mean variation between groups but an actual spread in ratings observed under different methods of test.

(2) For the commercial fuels, the maximum knock ratings usually fall within the total spread.

(3) The knock intensity ratings, made in each case at the speed of maximum knock for each of the commercial fuels, fall within a comparatively

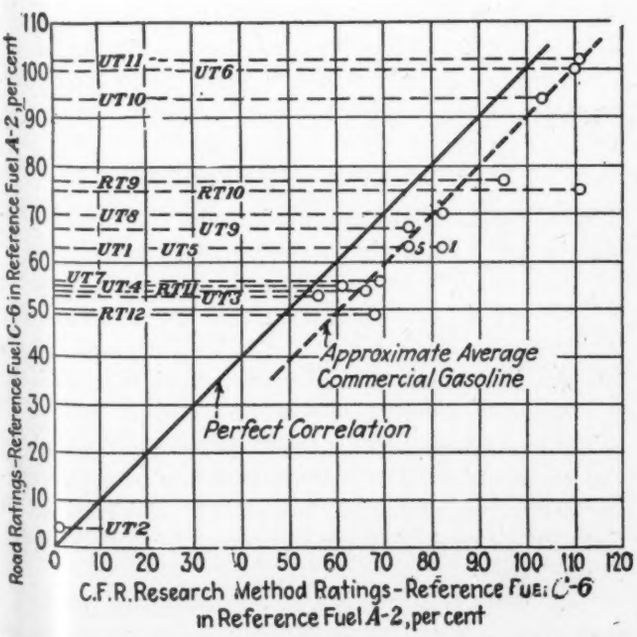


FIGURE 1—ROAD-TEST CORRELATION WITH C.F.R. ENGINE RATINGS DETERMINED UNDER C. F. R. RESEARCH METHOD

Test Conditions: Speed, 600 R.P.M.; Jackets, 212 Deg. Fahr.; Carbureter Set for Maximum Knock; Spark Timing, 22.5 Deg. at 5:1; Wide Open Throttle.

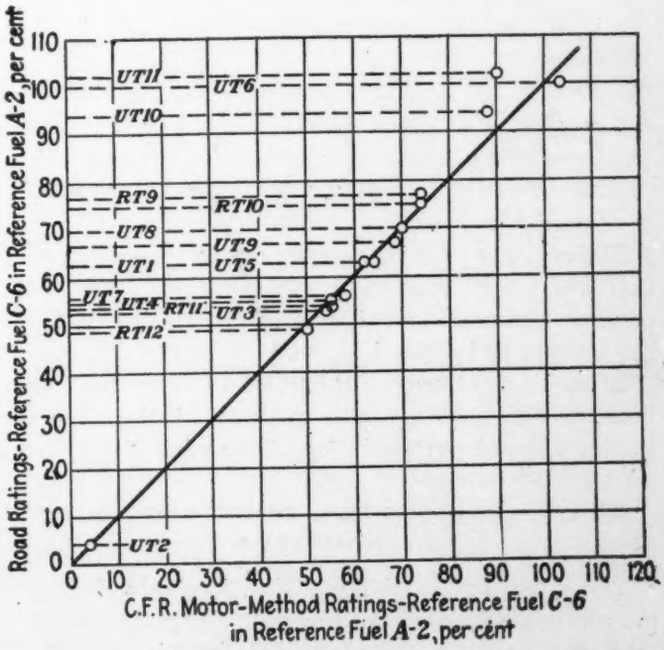


FIGURE 2—ROAD-TEST CORRELATION WITH C.F.R. ENGINE RATINGS DETERMINED UNDER C.F.R MOTOR METHOD

Test Conditions: Electric Mixture-Heater No. 2, Mixture, 300 Deg. Fahr.; Speed, 900 R.P.M.; Jacket, 212 Deg. Fahr.; Carbureter Set for Maximum Knock; Spark Timing, 26 Deg. at 5:1; Wide Open Throttle.

narrow range representing a maximum spread of about 5 octane numbers. For the straight cracked fuels the alignment is not so good, but the total spread is also greater. The getting of a representative road rating for these straight cracked fuels appears to be a matter of the very roughest approximation because of the wide divergences between cars.

The average of the maximum knock ratings for all cars on each fuel was agreed upon as the most satisfactory road rating for the fuels tested that the operating group was able to determine.

ROAD-TEST PROCEDURE DEVELOPED

On the basis of these data, the following road-test procedure was approved and adopted by the Detonation Subcommittee and later by the Cooperative Fuel-Research Steering Committee:

Road knock ratings on motor gasolines shall be made by a method involving a comparison between the sample to be rated and a reference fuel; this comparison to be made between the points of maximum knock of each fuel without regard to whether this point of maximum knock occurs at the same or different speeds for the sample and the reference fuel.

More specifically, in rating a fuel in a car by this method it is necessary to determine:

(1) The relative knock intensities produced by the sample at different speeds during either slow acceleration or slow deceleration.

(2) The relative knock intensities produced by the reference fuels at different speeds during a similar period of slow acceleration or deceleration. From these data the speed required to produce the maximum knock intensity for each fuel, that is, the sample and the reference fuel, is determined.

(3) Finally, the knock intensity produced by the sample at its speed for maximum knock is to be bracketed between knock intensities produced by two reference fuels at their maximum knock speed.

The rating is then expressed in terms of a reference fuel which will produce a maximum intensity that matches the maximum knock intensity produced by the sample to be rated.

In making ratings by this method, it is to be understood that they are to be made at full throttle and within a speed range of 15 to 50 m.p.h.

COOPERATIVE LABORATORY TESTS AT WAUKESHA

The modification of the C.F.R. knock-testing apparatus and procedure to correlate laboratory results with the results obtained by the newly established road-test method was unanimously determined upon as the next step in the undertaking.

H. L. Horning, president of the Waukesha Motor Company and an active member of the Detonation Subcommittee since its inception, generously offered complete facilities for conducting cooperative tests at the laboratory of his company. Accordingly, the second phase of the test program was started at Waukesha on August 24, and by dint of the most concentrated efforts, operations being planned on a basis of two shifts per day, the operating group assigned to this problem brought its work to a satisfactory conclusion in time to render a report at the September 12 meeting of the Cooperative Fuel-Research Steering Committee.

The correlation work at Waukesha was conducted with identically the same fuels that were used in the road tests at Uniontown, the remainder of the supply of fuels having been carefully transported by truck from Uniontown to Waukesha.

In accordance with the plan outlined at Uniontown to allow each organization participating in the work to be represented by one man, the following men and their respective organizations contributed to the work:

W. G. Ainsley, Sinclair Refining Company; H. W. Best, Yale University; J. M. Campbell, General Motors Corporation; W. M. Holaday, Standard Oil Company, (Indiana); K. L. Hollister, The Texas Company, G. A. Hope, Standard Oil Company of New York; L. A. Hunt, Ethyl Gasoline Corporation; C. B. Kass, Standard Oil Development Company; S. P. Marley, Vacuum Oil Company; T. B. Rendel, Shell Petroleum Corporation; G. C. Rogers, Bureau of Standards; J. R. Sabina, Atlantic Refining Company; C. B. Veal, Society of Automotive Engineers, Inc.; H. M. Wiles, Waukesha Motor Company.

In addition to these men, H. K. Cummings and N. R. White, of the Bureau of Standards, and K. T. Winslow and A. W. Pope, of the Waukesha Motor Company, rendered valuable assistance to the above-named operating group.

CHANGES IN C.F.R. APPARATUS

At the outset of the work, two changes in the standard C.F.R. engine were adopted, as follows:

(1) A shrouded intake valve designed to give the charge a swirling motion as it enters the intake port.

(2) An improved type of steam condenser and the elimination of the circulating pump.

These two changes proved effective throughout the work and, on the recommendation of the operating group, were formally adopted by the Detonation Subcommittee and later approved by the Steering Committee.

The first task before the laboratory operating group was to determine what degree of correlation existed between ratings made by the existing C.F.R. knock-testing procedure and the Uniontown road ratings. This correlation is shown in Figure 1, in

which the Uniontown ratings are plotted on the vertical axis against the C.F.R. ratings on the horizontal axis. Exact correlation between road ratings and laboratory ratings would be shown by points falling on the 45-deg. line midway between the two axes.

This chart shows a decided lack of perfect correlation and indicates that the average discrepancy between the C.F.R. engine ratings by the existing precedure and the road ratings was of the order of magnitude of 10 per cent of Reference Fuel C-6 in Reference Fuel A-2, or the equivalent of about 2.5 to 3.0 octane numbers for commercial fuels. In certain cases the discrepancy was greater.

Since these data established the fact that ratings made by the C.F.R. knock-testing procedure do not correlate with the road results, the problem resolved itself into one of modifying the existing C.F.R. procedure in such a way that more nearly perfect correlation could be obtained between the laboratory test and the road test. In making the necessary modifications, the Committee aimed to obtain the best correlation possible by the most practical means; that is, means which would involve the minimum amount of change in the existing equipment. An effort was made to reproduce normal automotive-operating conditions insofar as possible and to develop a method that would lend itself most readily to routine practice and by which knock ratings could be made on fuels varying in antiknock quality over a wide range.

With these principles in mind, certain engine operating variables, which several of the cooperating laboratories had previously found to be effective in modifying knock ratings, were selected; specifically, engine speed, mixture temperature, jacket temperature, throttle opening, valve timing and piston temperature. A study was made of the effect upon road-test correlation of changes in each of these variables, both singly and in various combinations.

Seven C.F.R. engines were placed at the disposal of the Committee at the Waukesha Motor Company's laboratory. Five of these engines were kept running constantly testing various modifications in the C.F.R. procedure. During the two and one-half weeks of test work, 68 modifications in procedure and approximately 650 individual knock ratings were made.

These tests constituted the major portion of the work, and as a result the following method was recommended as the most satisfactory from the standpoint of accomplishing good correlation with road ratings and without the attendant disadvantages of ethylene-glycol cooling which was included in the only suitable alternative method found:

The new C.F.R. Motor Method differs from the older method, now to be known as the C.F.R. Research Method, in five respects. It will be noted that the features of the new method as stated herewith involves certain definite changes in equipment and procedure. With the exception of these items listed below, the apparatus and procedure are essentially as published in the S.A.E. Journal for August, 1931, and in use as the C.F.R. Research Method.

(1) Speed: 900 r.p.m.
(2) Mixture temperature: 300 deg. fahr.; heat applied by an electric heating-unit placed between the carbureter and the intake port; the mixture temperature to be measured by a mercury thermometer whose bulb is placed in the center of the mixture stream entering the inlet port.
(3) Spark timing: 26 deg. before top center at 5:1 and following the present timing mechanism at other compression ratios.
(4) Shrouded intake-valve.
(5) An improved type of steam condenser and elimination of the circulating pump.

Further in making the specified changes in equipment it is absolutely necessary that every new part of the equipment, including the complete electric heater, thermometer, shrouded intake-valve, and condenser and water connection to replace the circulating pump, should be specifically those manufactured for this purpose by the Waukesha Motor Company.

Figure 2 shows the correlation between road ratings and ratings on the C.F.R. engine determined by this modified procedure. Table 1, giving the summary of ratings on the fuels tested at Uniontown, indicate clearly the almost perfect correlation between the road ratings of the fuels and the laboratory ratings according to the modified procedure, now termed the C.F.R. Motor Method, and shows the degree of improvement in this correlation over the ratings as obtained by the previous method that is, the C.F.R. Research Method.

Furthermore, the operating group, in rendering its report to the Detonation Subcommittee, expressed the belief that these modifications in the C.F.R. apparatus and procedure not only give better correlation with the actual performance tests than the former C. F. R. procedure, but the modified procedure will enable knock ratings to be made with greater speed and accuracy than heretofore.

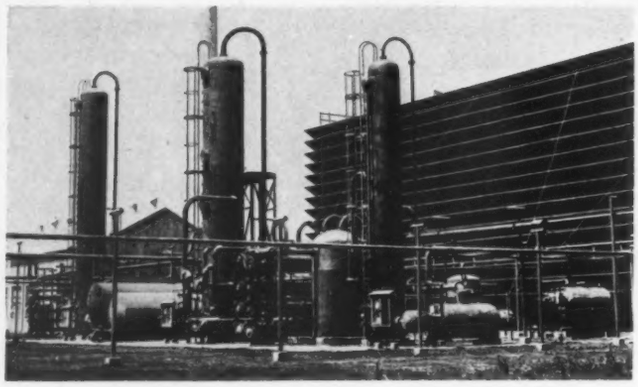
Acting upon the report of the operating group and the recommendation of the Detonation Subcommittee, the Cooperative Fuel-Research Steering Committee at its meeting on September 12, officially approved this modification of the knock-testing procedure to be known as the C.F.R. Motor Method.

The Steering Committee also approved the suggestion of the Detonation Subcommittee that the old C.F.R. method should not be discarded, since it is one on which considerable experience and data have been obtained and undoubtedly has value from the experimental standpoint, but should be retained under the title, C.F.R. Research Method.

HIGH PRESSURE

Gas Conditioning Plant Requires Additional Equipment

RECOVERY of the available salable hydrocarbons contained in the natural gas being transported through the largest line in the United States, owned and operated by Texoma Gas Company, has been through the erection of additional equipment not found in the ordinary plant processing natural gas. This plant was started operating about the first of September, 1931, with all the several units of Jackson Engineering Company design (Alco Products, Inc.). Pressures through the absorbers average around 575 pounds gauge in the summer months when deliveries are comparatively light but run considerably higher when the demand is greater and all of the 12, 1250 horse-power Worthington compressors are placed in service. The line through which this gas is transported to Chicago and intermediate points from the extensive fields near Fritch, Texas, is 24 inches in diameter and approximately 900 miles in length. These necessary high transportation pressures on the gas as it comes in contact with the absorption medium in the towers causes the oil to retain large quantities of the low fractions, principally propane, ethane and some methane, as well as those fractions which are to be retained and prepared for market.



High Pressure gas conditioning plant on the Texoma Gas Company pipe line, Fritch, Texas.

One part of the additional equipment is placed on the oil outlet from the high pressure absorbers which receives the oil at 315 pounds and is termed the high pressure fixed-gas eliminator. The oil is trapped from the base, while the gas which escapes from the oil is taken from the top and returned to the auxiliary compressor room and passed back to the transmission line beyond the absorbers. The oil entering the absorbers averages around 84°F. and leaves then from the high pressure fixed gas eliminator at 91°F. The gas enters at approximately the same temperature and leaves the top of the absorbers at around 98° F. to enter the drying equipment where practically all the moisture is extracted prior to its trip through the long line to points of consumption.

As this partially stabilized rich oil leaves the base of the high pressure fixed-gas eliminator, it is transferred through transfer lines to a high temperature fixed-gas eliminator which consists of a drum similar to the high pressure fixed-gas eliminator and a fractionating tower similar in construction to the final gasoline stabilizer but not as high and with only 20 trays with bubble caps. Before the rich oil enters this equipment, it is passed through the heat exchanger bank. Denuded oil from the conventional steam still is passed counter current to the flow of rich oil with a temperature of 358°F. The rich oil leaves the exchangers under an average temperature of 290°F. and a pressure of 292 pounds. As the rich oil carrying some of those undesirable fractions enters the receiving drum of the high temperature fixed-gas eliminator near the upper end, these fractions are released and pass out of the top. Oil is removed from the base through a liquid level controller and transferred to the still for further processing.

Those vapors escaping from the high temperature fixed-gas eliminator receiving drum are carried overhead and enter the vapor fractionating tower near the lower half. Standard high pressure vapor fractionation occurs in this tower. Fixed gasses which pass through the equipment in the vapor state are picked up from the overhead connections and passed back under 150 pounds pressure to the vapor fractionator compressors which boost the pressure back to 575 pounds for reentry to the transmission line.

The stabilized rich oil is passed to the still where it is processed under 40 pounds, usual pressures in natural gasoline recovery. Temperatures of 358°F. are maintained on the still, while the top is controlled by reflux to a temperature of 180°F. for product quality control. Uncondensed still vapors are passed through the recompressor which operates under 25 pounds intake and 205 pounds discharge. Final composition product is stabilized to meet market requirements.